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*THE CENTURY'S PROGRESS IN APPLIED MATHEMATICS.**

I.

THE honor of election to the presidency of the American Mathematical Society carries with it the difficult duty of preparing an address, which may be at once interesting and instructive to a majority of the membership, and which may indicate at the same time the lines along which progress may be expected in one or more branches of our favorite science. In partial recognition of the honor you have conferred upon me it has seemed that I could do no better than to consider with you some of the principal advances that have been made in mathematical science during the past century. But here at the outset one must needs feel sharply restricted by the limitations of his knowledge and by the wide extent of the domain to be surveyed. Especially must this be the case with one who belongs to no school of mathematicians, unless it be the 'old school' of inadequate opportunities and desultory training. On account of these conditions, I have found it essential to accept the ordinary division of the science into pure and applied mathematics and to confine my attention in this address wholly to applied mathematics. Here again, however, it is

* Address of the President of the American Mathematical Society, read December 28, 1899.

necessary to impose restrictions, for the domain thus divided is still far too large to be reviewed adequately in the brief interval allotted to the present occasion. I have therefore limited my considerations chiefly to those branches of applied mathematics which were already recognized as such at the beginning of the present century. The most important of these branches appear to be analytical mechanics, geodesy, dynamical astronomy, spherical or observational astronomy, the theory of elasticity, and hydromechanics. This rather arbitrary subdivision may be made to include several important branches not enumerated, while it must exclude others of equal or greater importance. Thus the theory of heat diffusion which led Fourier to the wonderful analysis which bears his name may be alluded to under physical geodesy; the theories of sound and light may be regarded as applications merely of the theories of elasticity and hydromechanics; while the theories of electricity, magnetism, and thermodynamics, which are the peculiar and perhaps most important developments of the present century, must be excluded almost altogether.

Another difficulty which besets one who would speak of the progress in question is that arising from the technicalities of the subjects to be discussed. Beautiful and important as these subjects are when arrayed in their mathematical dress, and thrilling as they truly are when rehearsed with appropriate terminology in the quiet of one's study, it must be confessed that they are on the whole rather uninviting for the purposes of semi-popular exposition. In order to meet this difficulty it seems best to relegate technicalities which demand expression in symbols to footnotes and, while freely using technical terminology, to translate it into the vernacular whenever essential. Thus it is hoped to avoid the dullness of undue condensation on the one hand, and the superficiality of mere literary description on the other.

The end of the last century marks one of the most important epochs in the history of mathematical science. This time, one hundred years ago, the master work of Lagrange (1736–1813), the Mécanique Analytique, had been published about eleven years. The first two volumes of the Mécanique Céleste of Laplace (1749–1827), undoubtedly the greatest systematic treatise ever published, had just been issued. Fourier (1768–1830), whose mathematical theory of heat was destined to play a wonderful rôle in pure and applied mathematics, was a soldier statesman in Egypt, where with Napoleon he stood before the pyramids while the centuries looked down upon them.* Gauss (1777–1855), who with Lagrange and Cauchy (1789–1857) must be ranked among the founders of modern pure mathematics, was a promising but little known student whose Disquisitiones Arithmeticae and other papers were soon to win him the directorship of the observatory at Göttingen. Poisson (1781–1840), to whom we owe in large part the beginnings of mathematical physics, had just started on his brilliant career as a student and professor in the École Polytechnique. Bessel (1784–1846), whose theories of observational astronomy and geodesy were destined soon to assume a prominence which they still hold, was an accountant in a trading house at Bremen. Dynamical astronomy, the favorite science of the day was under the dominating genius of Laplace, with no one to dispute his preëminence, and with only Lagrange and Poisson as friendly competitors in the same field. Rational mechanics as we now know it, was soon to

* The bombastic words of Bonaparte, "Songez que du haut de ces pyramides quarante siècles vous contemplent," may be excused, perhaps, in view of the fact that Fourier, Monge, and Berthollet were present on the occasion.

be simplified and systematized by Poinsot (1777–1859), Poisson, Möbius (1790–1868), and Coriolis (1792–1843), who were all at this time under twenty-five years of age. The undulatory theory of light, in which Young (1773–1829), Fresnel (1788–1827), Arago (1786–1853), and Green (1793–1841) were to be the most conspicuous early figures, was just beginning to be considered as an alternative to the emission theory of Newton. The theory of elasticity, or the theory of stress and strain as it is now called, was about to be reduced to the definiteness of formulas at the hands of Navier (1785–1836), Poisson, Cauchy, and Lamé (1795–1870). Planetary and sidereal astronomy, to which so much of talent, time, and treasure have since been devoted, was soon to receive the fruitful impetus imparted to it by the German school of Gauss, Bessel, Encke (1791–1865), and Hansen (1795–1874).

The advances that have been made during the past century in analytical mechanics must be measured from the elevated standard attained by Lagrange in his Mécanique Analytique. To work any improvement over this, to simplify its demonstrations, or to elaborate its details, was a task fit only for the keenest intellects. Lagrange had, as he supposed, reduced mechanics to pure mathematics. Geometrical reasonings and diagrammatic illustrations were triumphantly banished from this science and replaced by the systematic and unerring processes of algebra. "Ceux qui aiment l'Analyse," he says, "verront avec plaisir la Mécanique en devinir une nouvelle branche, et me sauront gré d'en avoir étendu ainsi le domaine." The mathematical world has not only accepted Lagrange's estimate of his work, but has gone further, and considers his achievement one of the most brilliant and important in the whole range of mathematical science. "The mechanics of Lagrange," as Mach has well said, "is a stupendous contribution to the economy of thought."*

Nevertheless, improvements were essential, and they came in due time. As we can now see without much difficulty, Lagrange and most of his contemporaries in their eagerness to put mechanics on a sound analytical basis overlooked to a serious extent its more important physical basis. The prevailing mathematical opinion was that a science is finished as soon as it is expressed in equations. One of the first to protest against this view was Poinsot, though the preëminent importance of the physical aspect of mechanics did not come to be adequately appreciated until the latter half of the present century. The animating idea of Poinsot was that in the study of mechanics one should be able to form a clear mental picture of the phenomena considered; and that it does not suffice to put the data and the hypotheses into the hopper of our mathematical mill and then to trust blindly to its perfection in grinding the grist. In elaborating this idea he produced two of the most important elementary treatises on mechanics of the century. These are his Éléments de Statique published in 1804, and his Théorie Nouvelle de la Rotation des Corps published in 1834.† In the former work he developed the beautiful and fruitful theory of couples and their composition, and the conditions of equilibrium, as they are now commonly expressed in elementary books.

* The Science of Mechanics, by Dr. Ernst Mach. Translated from the German by Thomas J. McCormack. Chicago, Open Court Publishing Co., 1893.

† Outlined to the Paris Academy in 1834. In the introduction to the edition of 1852 he says, "Voici une des questions qui m'ont le plus souvent occupé, et, si l'on me permet de parler ainsi, une des choses que j'ai le plus désiré de savoir en dynamique.

"Tout le monde se fait une idée claire du mouvement d'un point, * * * Mais, s'il s'agit du mouvement d'un corps de grandeur sensible et de figure quel-conque, il faut convenir qu'on ne s'en fait qu'une idée très-obscure."

In the latter he took up the more recondite question of rendering a clear account of the motion of a rigid body. This problem had been treated already by the illustrious Euler, d'Alembert, Lagrange, and Laplace, and it seemed little short of temerity to hope for any improvement. But Poinsot entertained that hope and his efforts proved surprisingly successful. His little volume of about one hundred and fifty pages is still one of the finest models of mathematical and mechanical exposition; and his repeated warning, "gardons-nous de croire qu'une science soit faite quand on l'a réduite à des formules analytiques," has been fully justified. He gave us what may be called the descriptive geometry of the kinetics of a rotating rigid body, the 'image sensible de cette rotation'; he clarified the theory of moments of inertia and principal axes; he made plain the meaning of what we now call the conservation of energy and the conservation of moment of momentum of systems which are started off impulsively; and he surpassed Laplace himself in expounding the theory of the invariable plane.

Another elementary work of prime importance in the progress of mechanics was Poisson's Traité de Mécanique. Poisson belonged to the Lagrangian school of analysts, but he was so profoundly devoted to mathematical physics that almost all his mathematical work was suggested by and directed towards practical applications. His facility and lucidity in exposition rendered all his works easy and attractive reading, and his treatise on mechanics is still one of the most instructive books on that subject. He was one of the first to call attention to the value of the principle of homogeneity in mechanics,* a principle which, as expanded in Fourier's theory of dimensions,† has proved of the greatest utility in the latter half of the century. The influence of Poisson's work in mechanics proper, very widely extended, of course, by his memoirs in all departments of mathematical physics, is seen along nearly every line of progress since the beginning of the century.

Of other works which paved the way to the present advanced state of mechanical science, it may suffice to mention the Cours de Mécanique* of Poncelet (1788–1867), the Traité de Mécanique des Corps Solides et de l'Effet des Machines† of Coriolis, and the Lehrbuch der Statik‡ of Möbius. To the two former of these authors we owe the fixation of ideas and terminology concerning the doctrine of mechanical work, while the suggestive treatise of Möbius foreshadowed a new type of mechanical concepts since cultivated by Hamilton (Sir W. R., 1805–1865). Grassmann (1809–1877), and others under the general designation of vector analysis.

Following close after the development of the elementary ideas whose history we have sketched came the important improvements in the Lagrangian analysis due to Hamilton.§ With these additions of Hamilton, amplified and clarified by the labors of Jacobi, Poisson, and others,‖ analytical mechanics may be said to have reached its present degree of perfection so far as mathematical methods are concerned. By these methods every mechanical question may be stated in either of three characteristic though interconvertible ways, namely: by the equations of d'Alembert,

* See Article 23, Tome I., Traité de Mécanique, 2d ed., Paris, 1833.

† 'Théorie Analytique de la Chaleur,' Paris, 1822.

* Metz, 1826.

† Paris, 1829.

‡ Leipzig, 1837.

§ 'On a general method in dynamics.' *Philosophical Transactions*, 1834–35.

‖ For an account of these additions and for a complete list of papers bearing on the subject (up to 1857), one should consult the admirable report of Cayley on 'Recent progress in dynamics,' published in the Report of the British Association for the Advancement of Science for 1857.

by the equations of Lagrange, and by the equation of Hamilton. Each way has special advantages for particular applications, and together they may be said to condense into the narrow space of a few printed lines the net results of more than twenty centuries of effort in the formulation of the phenomena of matter and motion.

Such was the state of mechanical science when the great physical discovery of the century, the law of conservation of energy, was made. To give adequate expression to this law it was only necessary to recur to the Mécanique Analytique, for herein Lagrange had prepared almost all of the needful machinery. So well indeed were the ideas and methods of Lagrange adapted to this purpose that they have not only furnished the points of departure for many of the most important discoveries* of the present half century, but they have also supplied the criteria by means of which mechanical phenomena in general are most easily and effectively defined and interpreted.

Of the special branches of analytical mechanics which have undergone development during this century, by far the most important is that known as the theory of the potential function. This function first appeared in mathematical analysis in a memoir of Lagrange in 1777† as the expression of the perturbative function, or force function. It next appeared in 1782‡ in a memoir by Laplace. In this memoir Laplace's equation§ appears for the first time, being here expressed in polar coördinates. In 1787* the same equation appears in the more usual form as expressed by rectangular coördinates.

Strange as it now seems when viewed by the light of this end of the century, nearly thirty years elapsed before Laplace's equation was generalized. Laplace had found only half of the truth, namely, that which applies to points external to the attracting masses.† Poisson discovered the other half in 1813.‡ Thus the honors attached to the introduction of this remarkable theorem are divided between them, and we now speak of the equation of Laplace and the equation of Poisson, though the equation of Poisson includes that of Laplace.

Next came the splendid contributions of George Green under the modest title of "An essay on the application of mathematical analysis to the theories of electricity and magnetism."§ It is in this essay that the term 'potential function' first occurs. Herein also his remarkable theorem in pure mathematics, since universally known as Green's theorem, and probably the most important instrument of investigation in the whole range of mathematical physics, made its appearance.

We are all now able to understand, in a general way at least, the importance of Green's work, and the progress made since the publication of his essay in 1828. But fully to appreciate his work and subsequent progress, one needs to know the outlook for the mathematico-physical sciences as it appeared to Green at this time, and to realize his refined sensitiveness in promulgating his discoveries.

* Especially those in the theories of electricity, magnetism, and thermodynamics.

† *Nouveaux Mémoires de l'Académie des Sciences et Belles Lettres de Berlin.* See also remarks of Heine, Handbuch der Kugelfunctionen, Band II., p. 342.

‡ *Paris Memoires* for 1782, published in 1785.

§ $$\Delta^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0.$$

$\Delta^2 V$ is called the Laplacian of V.

* *Paris Memoires* for 1787, published in 1789.

† That is, Laplace's equation is $\Delta^2 V = 0$, while Poisson's is $\Delta^2 V + 4\pi k\rho = 0$, V being the potential and ρ the density at the point (x, y, z), and k being the gravitation constant.

‡ Poisson's equation was derived in a paper published in *Nouveau Bulletin* * * * *Société Philomatique*, Paris, Dec., 1813.

§ Nottingham, 1828.

"It must certainly be regarded as a pleasing prospect to analysts," he says in his preface, "that at a time when astronomy from the state of perfection to which it has attained, leaves little room for further applications of their art, the rest of the physical sciences should show themselves daily more and more willing to submit to it. * * * Should the present essay tend in any way to facilitate the application of analysis to one of the most interesting of the physical sciences, the author will deem himself amply repaid for any labor he may have bestowed upon it; and it is hoped the difficulty of the subject will incline mathematicians to read this work with indulgence, more particularly when they are informed that it was written by a young man, who has been obliged to obtain the little knowledge he possesses, at such intervals and by such means, as other indispensable avocations which offer but few opportunities of mental improvement, afforded." Where in the history of science have we a finer instance of that sort of modesty which springs from a knowledge of things?

The completion of the potential theory, so far as it depends on the Newtonian law of the inverse square of the distance, must be credited to Gauss, though a host of writers has since contributed many valuable additions in the way of details. Early in the century Gauss had begun the study of the absorbing problems of the day, namely, problems of attractions and repulsions. The prevailing notion of mathematical physicists seems to have been that all mechanical phenomena may be attributed to attractions and repulsions between the ultimate particles of matter and the ultimate particles of 'fluids' associated with matter. The difficulties of action at a distance, without the aid of an intervening medium, happily, did not trouble them at that time; for who shall say that their labors would have been more fruitful if they had stopped to remove these difficulties? Gauss's first memoir in this field relates to the attractions of homogeneous ellipsoidal masses,* and dates from 1813. It was in this memoir that he published a number of the elegant theorems† which are now found in the elementary books on the theory of the potential function. In 1829 he published his theory of fluid figures in equilibrium,‡ and in 1832 there followed one of the most important papers of the century on the intensity of terrestrial magnetic force expressed in what we now call absolute units.§ Six years later he published his wonderful theory of the earth's magnetism‖ and applied it to all existing observational data. This theory is a splendid application of the potential theory, and his entire investigation is one of the most beautiful and useful contributions to mathematical physics of the century. Well was he qualified, therefore, to complete the theory of the Newtonian potential function in the collection of theorems published in his memoir¶ of

* 'Theoria attractionis corporum sphaeroidicorum ellipticorum homogeneorum,' 1813. See Gauss's Werke, Band V., Göttingen, 1877.

† Especially the theorem giving the values of the surface integral

$$\int \frac{\cos(s, n)}{s^2} dS,$$

where dS is an element of any closed surface, s the distance from dS to any fixed point, and n indicates the normal to the surface at dS. This gave the key to the very important theorem of the surface integral of the normal acceleration, or

$$\int \frac{\partial V}{\partial n} dS.$$

‡ 'Principia generalia theoriæ figuræ fluidorum in statu æquilibrii,' 1829. Werke, Band V.

§ 'Intensitas vis magneticæ terrestris ad mensuram absolutam revocata.' Werke, Band V.

‖ Allegemine Theorie des Erdmagnetismus. Werke, Band V.

¶ 'Allegemine Lehrsätze in Beziehung auf die im verkehrten Verhältnisse das Quadrats der Entfernung wirkenden Anziehungs- und Abstossungs-Kräfte.' Werke, Band V.

1840. This is still the fundamental memoir on the subject of which it treats, and must be regarded as one of the most perfect models of mathematical exposition. In respect to clearness and elegance, indeed, the works of Gauss are unsurpassed. "In his hands," as Todhunter has said,* "Latin and German rival French itself for clearness and precision." "Alles gestaltet sich neu unter seinen Händen," was the tribute† of Bessel; and the lapse of two generations has served only to increase admiration for the genius and industry which made Gauss one of the most conspicuous figures in the science of the nineteenth century.

The importance of the theory of the potential function when considered in its historical aspects is found to consist not so much in the rich harvest of results it has afforded in the field of gravitation, as in its direct bearing on the developments of other branches of mathematical physics. For the points of view and the analytical methods of the Newtonian function have been adapted and extended with brilliant success to the interpretation of almost all kinds of mechanical phenomena. Thus it has come about that we have now to deal with many kinds of potential, as logarithmic potential, velocity potential, displacement potential, electric potential, magnetic potential, thermodynamic potential, etc., each of which bears a more or less close mathematical analogy to the Newtonian function.

In the closing paragraph of his Exposition du Système du Monde, Laplace refers to the immense progress made in astronomy since the geocentric theory was displaced by the heliocentric theory of the solar system. This progress is specially remarkable when we consider that it depended on the discovery, so humiliating to man, of the relatively insignificant dimensions and inconspicuous rôle of our planet. But we agree with Laplace that "Les resultats sublimes auxquels cette découverte l'a conduit sont bien propres à le consoler du rang qu'elle assigne à la Terre, en lui montrant sa propre grandeur dans l'extrême petitesse de la base qui lui a servi pour mesurer les cieux." All astronomy is based on a knowledge of the size, the shape and the mechanical properties of the earth; and it is not surprising, therefore, that a large share of the mathematical investigations of the century should have been directed to the science of geodesy. Founded in the middle of the last century by Clairaut* and his contemporaries; recast by Laplace and Legendre† (1752–1833) in the early part of this century; systematized and extended to a remarkable degree by the German geodesists, led especially by the incomparable Bessel;‡ this science has now come to occupy the leading position in point of perfection of methods and precision of results. So great, in fact, has been the growth of this science during the century that recent writers have found it desirable to subdivide the subject into two parts called mathematical geodesy and physical geodesy respectively, though both parts are nothing if not mathematical.§

In a former address I have considered somewhat in detail certain of the more

* History of the Theories of Attraction and Figure of the Earth, Vol. II., p. 235.

† In a letter to Olbers, 1818.

* Clairaut's work, Théorie de la Figure de la Terre, Paris, 1743, was the pioneer work in physical geodesy.

† The name of Legendre is famous in geodesy by reason of his beautiful theorem which makes the solution of a geodetic triangle almost as easy as the solution of a plane triangle.

‡ Bessel's contributions to astronomy and geodesy are collected in Abhandlungen von F. W. Bessel, herausgegeben von Rudolf Engelmann, in drei Bänden, Leipzig, Wilhelm Engelmann, 1875.

§ See, for example, Die Mathematischen und Physikalischen Theorieen der Höheren Geodäsie von Dr. F. R. Helmert, Leipzig, B. G. Teubner, Teil I., 1880; Teil II., 1884.

salient mathematical problems which have arisen in the study of the earth ;* and the present review may hence be restricted to a rapid résumé of the less salient but perhaps more recondite problems, and to the briefest mention of problems already discussed.

Adopting the convenient nomenclature of geologists, we may consider the earth as made up of four parts, namely, the atmosphere; the hydrosphere, the oceans; the lithosphere, or crust, and the nucleus. Beginning with the first of these we are at once struck by the fact that much greater progress has been made during the century in the investigation of the kinetic phenomena of the atmosphere than in the study of what may be called its static properties. Evidently, of course, the phenomena of meteorology are essentially kinetic, but it would seem that the questions of pressure, temperature and mass distribution of the atmosphere ought to be determined with a close approximation from purely statical considerations. This appears to have been the view of Laplace, who was the first to bring adequate knowledge to bear upon such questions. He investigated the terrestrial atmosphere as one might investigate the gaseous envelope of an unilluminated planet.† He reached the conclusion that the atmosphere is limited by a lenticular-shaped surface of revolution whose polar and equatorial diameters are about 4.4 and 6.6 times the diameter of the earth respectively, and whose volume is about 155 times that of the earth.‡ If this conclusion be true our atmosphere should reach out to a distance of about 26,000 miles at the equator and to a distance of about 17,000 miles at the poles. It does not appear, however, that Laplace attempted to assign the distribution of pressure and density, and hence total mass of the atmosphere within this envelope; and I am not aware that any subsequent investigator has published a satisfactory solution of this apparently simple problem.*

*On the Mathematical Theories of the Earth. Vice-presidential address before Section of Astronomy and Mathematics of the American Association for the Advancement of Science, 1889. *Proceedings of A. A. A. S.*, for 1889.

† Mécanique Céleste, Livre III., Chap. VII., and Livre X., Chapts. I.–IV.

‡ Laplace's equation to a meridian section of this envelope is

$$x^{-1} - x_0^{-1} + \tfrac{1}{2}ax^2\cos^2\phi = 0,$$

where $x = r/a$, r being the radius vector measured from the center of the earth and a the mean radius of the earth ; a is the ratio of centrifugal to gravitational acceleration at the equator of the earth ; ϕ is geocentric latitude, and x_0 is the value of x for $\phi = \pi/2$.

The problem of the statical properties of the atmosphere may be stated in three equations, namely :

$$\Delta^2 V + 4\pi k\rho - 2\omega^2 = 0,$$
$$dp = \rho dV,$$
$$p = f(\rho, \tau).$$

In these V is the potential at any point of the atmosphere; p, ρ, τ being the pressure, density and temperature at the same point ; k is the gravitation constant ; and ω is the angular velocity of the earth. The above equation of Laplace neglects the mass of the atmosphere in comparison with the mass of the rest of the earth. An essential difficulty of the problem lies in the unknown form of the function $f(\rho, \tau)$.

* I have sought a solution with a view especially to determine the mass of atmosphere. A class of solutions satisfying the mechanical conditions of the following assumptions has been worked out. Thus, assuming $p = c\rho^m$, which includes the adiabatic relation, $p = c\rho^{1.41}$, and the famous Laplacian relation, $\partial p/\partial\rho = 2c\rho$; and the law of Charles and Gay-Lussac, $p = C\rho\tau$; there results

$$\frac{p}{p_0} = \left(\frac{Q}{Q_0}\right)^{\frac{m}{m-1}}, \quad \frac{\rho}{\rho_0} = \left(\frac{Q}{Q_0}\right)^{\frac{1}{m-1}}, \quad \frac{\tau}{\tau_0} = \frac{Q}{Q_0},$$

where $Q = x^{-1} - x_0^{-1} + \tfrac{1}{2}ax^2\cos^2\varphi$

defined above ; Q_0 is the value of Q for $x = 1$ and $\phi = \pi/2$; and p_0, ρ_0, τ_0 are the values of p, ρ, τ at the same point ($x = 1$, $\phi = \pi/2$).

Using the adiabatic law the above formula for ρ leads to a mass for the atmosphere of about 1/1200th of the entire mass of the earth. But since the adiabatic law gives too low a pressure, density and temperature gradient, this can only be regarded as an upper limit to the mass of the atmosphere. A lower limit of about 1/1000000th of the earth's mass is found by assuming that the mass of the atmosphere is equal to the mass of water or mercury which would give an equivalent pressure at the earth's surface.

On the other hand, the general character of the circulation of the atmosphere and the meteorological consequences thereof, have been brought within the domain of mathematical research, if they have not yet been wholly reduced to quantitative precision. The pioneer in this work was a fellow-countryman, William Ferrel (1817–1891),* who, like Green, came near being lost to science through the obscurity of his early environment. It is a curious though lamentable circumstance, illustrating at once the peculiar shyness of Ferrel and the proverbial popular indifference to discoveries which cannot be patented, that a man who had mastered the Principia and the Mécanique Céleste and who had laid the foundation of our theory of the circulation of the atmosphere, should have found no better medium for the publication of his researches than the semi-popular columns of a journal devoted to medicine and surgery. But such was the medium through which Ferrel's 'Essay on the Winds and Currents of the Ocean' appeared † in 1856. Since that time notable progress has been made at the hands of Ferrel, Helmholtz (1821–1894), Oberbeck, Bezold and others ;‡ so that we may entertain the hope that the apparently erratic phenomena of the weather will presently yield to mathematical expression, just as the similar phenomena of oceanic tides and terrestrial magnetism have already yielded to the power of harmonic analysis.

* For a biography and autobiographical sketch of Ferrel, and a list of his publications, see Biographical Memoirs of the National Academy of Sciences, Vol. III., pp. 265–309. Washington, 1895.

† In *Nashville Journal of Medicine and Surgery*, Oct. and Nov., 1856.

‡ Some of the most important papers and memoirs on this subject, collected and translated by Professor Cleveland Abbe, have been published by the Smithsonian Institution under the title 'The Mechanics of the Atmosphere.' Smithsonian Miscellaneous Collections, No. 843, Washington, 1891.

When we pass from the atmosphere to the hydrosphere, several questions concerning the nature and properties of their common surface, or what is usually called the sea surface, immediately demand attention. The most important of these are what may be distinguished as the static and the kinetic phenomena of the sea surface. Since tidal oscillations belong more properly to hydrokinetics, we may here confine attention to the static phenomena.

Starting from the datum plane fixed by Laplace, the most important contribution to the theory of physical geodesy since his time is the remarkable memoir of Sir George Gabriel Stokes 'On the Variation of Gravity at the Surface of the Earth.'* Adopting the hypothesis of original fluidity, or the more general hypothesis of a symmetrical arrangement of the strata of the earth, with increasing density towards the center, Laplace had shown that the acceleration of gravity in passing from the equator to the poles should increase as the square of the sine of the latitude.† This conclusion agreed well with the facts of observation ; and Laplace rested content in the opinion that his hypothesis was verified. But Stokes showed that the law of variation of the acceleration of gravity at the surface of the sea is wholly determined by that surface, regardless of the mode of distribution of the earth's mass. This, as we now see, of course, is a direct result of the theory of the potential function ; for the sea surface is an equipotential surface, and since it is observed to be closely spheroidal, the formula of Laplace follows independently of all hypothesis save that of the law of gravitation. But while Laplace's formula

* Read April, 1849. See Mathematical and Physical Papers by G. G. Stokes, Cambridge University Press, 1883, Vol. II.

† Laplace's formula is $g = \alpha + \beta \sin^2\phi$, where α is the value of g at the equator, β is a constant, and ϕ is the latitude of the place.

and the arguments by which he reached it throw no light on the distribution of the earth's mass, a slight extension of his methods gives a formula which shows that any considerable difference in the equatorial moments of inertia of the earth would produce a variation in the acceleration of gravity dependent on the longitude of the place of observation.* Thus it is possible by means of pendulum observations alone to reach the conclusion that the mass of the earth is very nearly symmetrically distributed with respect to its equator and with respect to its axis of revolution.

A question of great interest with which the acceleration of gravity at the sea surface is closely connected is that of the earth's mass as a whole. About two years ago I published a short paper which gives the product of the mean density of the earth and the gravitation constant in terms of the coefficients of Laplace's formula and the dimensions of the earth.† It was shown that this product can be easily computed from existing data to five significant figures with an uncertainty of only one or two units in the last figure; thus making it possible to obtain the mass of the earth to a like degree of precision if the constant of gravitation can be equally well determined. In a subsequent communication to this Society it was explained that the product in question is equal to 3π divided by the square of the periodic time of an infinitesimal satellite which would pass around the earth just grazing the equator if there were no atmosphere to impede its progress. The periodic time of such a satellite would be 1 hour, 24 minutes, 20.9 seconds. Attention is called to this subject with the hope that some mathematician may point out another possible relation between the gravitation constant and the mean density of the earth which can be accurately observed, or that some physicist may show how the gravitation constant can be measured directly with a precision extending to five significant figures.

The lithosphere is the special province of the geologist, and we may hence pass on to the nucleus, or chief part of the mass of the earth. Much time and attention have been devoted to the study of the important but intricate problems which the geometers of the early part of the century left to their successors. But while the obscurities and vagaries of our predecessors have been cleared away, it must be confessed that our improved mathematical apparatus has not brought us very far ahead of the positions of Laplace and Fourier as regards the constitution and properties of the nucleus. With respect to the law of the distribution of density in the nucleus it may be said that although Laplace's law* is probably not ex-

* See Helmert, Geodäsie, Band II., p. 74. The expression for the acceleration is

$$g = a + \beta \sin^2\phi + \gamma \cos^2\phi \cos 2\lambda,$$

where a, β, γ are constants, and ϕ, λ are latitude and longitude respectively; and the constant γ involves the difference of the equatorial moments of inertia as a factor.

† See *The Astronomical Journal*, No. 424. This product is expressed thus:

$$k\rho = \frac{2\pi}{T^2} + \frac{3(as_1 + \beta s_2)}{4\pi a\sqrt{1-e^2}};$$

wherein k is the gravitation constant, ρ is the mean density of the earth, T is the number of mean solor seconds in a sidereal day, a and β are the first two constants in the formula $g = a + \beta \sin^2\phi + \gamma \cos^2\phi\cos 2\lambda$ for the acceleration of gravity at the sea surface in latitude φ and longitude λ; a is the half major axis and e is the eccentricity of the earth's spheroid; and

$$s_1 = \frac{1}{2}\left\{1 + \frac{1-e^2}{2e}\log\frac{1+e}{1-e}\right\},$$

$$s_2 = \frac{1-e^2}{4e^2}\left\{\frac{2e}{1-e^2} + \log\frac{1-e}{1+e}\right\}.$$

The resulting numerical value is

$$k\rho = 36797 \times 10^{-11}/(\text{second})^2.$$

* The Laplacian distribution of pressure, density, and potential in the earth are defined essentially (neglecting the effect of rotation) by the three following equations:

act it is yet quite as nearly correct as our observed information requires.*

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(*To be concluded.*)

THE POSITION THAT UNIVERSITIES SHOULD TAKE IN REGARD TO INVESTIGATION.†

WHAT position shall universities take with regard to investigation? When the honor was done me of asking me to take part in this discussion, my first thought, after the sensation of complacency at the compliment, was that there could hardly be a *discussion* where all held probably very nearly the same views, and that the great difficulty would be to say anything that would not be better said by another. Then as I began to think more carefully, I saw that the question was not, as I had at first imagined it to be, "what shall universities do to encourage those on their staffs to investigate?" It is far wider than that. It comprises a whole group of questions concerning which there may be every shade of opinion. So the more I thought, the more I admired the wisdom the committee had shown in their choice of a subject. Later still, it dawned upon me that surely it is a most satisfactory sign of progress that this Society should meet to discuss such a subject, with the conviction that, though without the shadow of a legal right to make claims, we are, nevertheless, sure of a sympathetic hearing from both universities and the public.

First of all let us consider the place of investigation in education, as a means of mental training, quite apart from any definite results. Surely this alone opens a wide field for one afternoon's ramble, in which there are diverging and recrossing paths enough to furnish us the surprises of unexpected partings and unhoped-for reunions.

I would here remark that perhaps some confusion is possible from different interpretations of the word 'investigation.' According to some it means simply practical work, object teaching, or, better still, object study. According to others it is the search for something new. With regard to the value of the former we are all pretty well agreed. We do not need to be told what an advance it is over the old way of learning the statements of others concerning matters well within the sphere of observation. It may sometimes be carried too far, but in view of its great usefulness we will not quarrel with a little abuse. With what is meant by the second interpretation the case is different. Excepting some singularly gifted natures, it does not, in my opinion, concern the student. The universal or even the very general application of this method is the result of an extreme reaction. It rests on a fallacy. Because investigation is a good thing, and worthy of encouragement, which all must admit, it is assumed to be good for all, and an accepted method of education, which conclusion I cannot adopt. It is for the beginner to learn what is worth learning in his particular field first of all. It is not easy in these days to learn all that is worth learning even in a very restricted department. To start on investigation with this only half-learned is a direct

$$\Delta^2 V + 4\pi k\rho = 0,$$
$$dp = \rho dV,$$
$$\frac{\partial p}{\partial \rho} = c\rho;$$

where p, ρ, V are the pressure, density, and potential at any point of the mass, k is the gravitation constant, and c is a constant securing the equality of the members of the last equation.

* With regard to what constitutes an adequate theory in any case, see an instructive paper by Dr. G. Johnstone Stoney on 'The kinetic theory of gas, regarded as illustrating nature.' *Proceedings Royal Dublin Society*, Vol. VIII. (N. S.), Part IV., No. 45.

† Discussion before the American Society of Naturalists at the New Haven Meeting, December 25, 1899

injury to the student, whom it turns to premature specialization. It is both foolish and cruel to exact investigation as a part of the regular training of every student, and very unjust to imply that those whose taste does not lie that way are mentally inferior to those who dabble in research, no matter how ineffectively. It may be replied that, granting this, still it is a good and necessary training for those who in after life are to become investigators. I incline to dissent still, for the born investigator (and no other is worth much trouble) no more needs encouragement to investigate than the fish does to swim. I would, if anything, restrain him till his education has become broad and his mind mature. He will very quickly more than make up the lost time. Then let him have every encouragement.

As regards education I speak as a professor in a medical school, whose career has been so placed that he has seen this school develop into a department of a university. I feel that, in common with others, it has reached a point when it is in danger from the side of its scientific friends who mistake or will not learn the true purpose of a medical school. I so rarely find myself in complete accord with Huxley, that I cannot forbear, though it is not for the first time, quoting his deliberate opinion, that whoever adds one tittle that is unnecessary to medical education is guilty of a very grave offense. If this be true, as I firmly believe it is, we must look to it that the candidate for the degree of M.D. be not robbed of his time, none too long for learning medicine as an art, by specially conducted excursions into abstract science. It may be said, and said truly, that without such auxiliaries the education of the student wants something of the breadth which his should have who aspires to stand on the pinnacle; but this only emphasizes the fact, now becoming daily clearer, that there has grown up the need of what may be called advanced medicine. Some would have this strictly post-graduate, but it is probably wiser to have a difference in the course. On the one hand there is the young man who aspires to be a conscientious every-day practitioner of medicine, looking forward to a life of hard work among suffering humanity. Such a one is not to be refused the degree of an honored university, and told superciliously to go to the little school round the corner. Neither is he who, looking at the matter more as a scholar, desires through his studies to train himself to teach others and to widen the horizon of knowledge, to be told that we have no help to offer to one of his ideals. We must provide for both; but with what power I have I shall always protest against sacrificing the first to the second, though the latter is the one with whom my tastes incline me to sympathize.

To sum up thus far, I conclude that it is not the duty of universities to urge, still less to force, original investigation upon students. It should be at hand for those whose zeal is so great that it will take no denial.

The next question is what universities should do for research in the community at large. Are more prizes and scholarships to be offered? As to prizes I should hesitate to say yes. It is not well that they should be too common; but of scholarships for deserving men we can hardly have too many. It is most desirable that the universities should award them. They cannot, indeed, give the funds, but, these being provided, committees from the universities should give their time, care and experience to their proper administration. This is a most beneficent and dignified attitude for a university, midway between the generous donor and the deserving student, to see that the generosity of the former is neither neglected nor abused.

The next and last aspect of the question that I shall consider is "what shall a uni-

versity do for the support and encouragement of investigators within its walls?" The primary function, in my opinion, of a professor is to teach; but, with certain exceptions of rare merit, it is necessary for his reputation and influence that he should do original work. The first duty of the university to him is that he should not be overburdened with teaching. The next problem is, how the expenses of his work are to be met. These must vary with the department. For some lines of research distant expeditions are requisite, necessarily so costly that they can hardly be provided for otherwise than by national or private munificence. But putting these aside, and speaking more particularly of biological and morphological work, the problem reduces itself to this: what help shall the university give to the investigator, (1) in the matter of providing the material, namely, the subject matter for the study, (2) the machinery and reagents for the work, (3) the means of illustrating it, and finally of publishing the paper. The last need is not urgent on account of the great number of journals of all kinds, but it exists in isolated cases. Till comparatively recently the position of universities has been much like that of the Pickwick Club, which when sending its honored founder and his companions on their travels saw no objection to every member paying his own bills. But professors for the most part suffer from 'that perpetual lack of pence which vexes public men,' and those who are not yet professors are, of course, vexed the more. Is it fair that a serious tax, ever increasing in direct ratio to his merit, should be laid on the investigator, especially as the university profits in no small degree by his success? I am sure we shall all agree it is not. But then difficulties present themselves as to how this help is to be given and distributed, assuming that the university admits the claim. Who are to be the chief beneficiaries? The most distinguished or the most needy? The oldest because of his years? Or the youngest because of his youth? And again is it just that the university should furnish large sums for bringing out papers of unknown merit? It seems to me that the most feasible way, if the money can be procured, is to place a sum in the hands of the professor at the head of each scientific department, to be spent for the good of that department, including publication, according to his discretion, or his lack of it. Should the latter be painfully apparent, the resulting unpopularity will surely be irresistible, and thus there will be a check on a system which may at first seem too arbitrary.

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THE primary function of a university is the diffusion of knowledge, and it is, I believe, equally true that these higher institutions of learning are in great part responsible for the extent to which knowledge is spread throughout the land. Before there can be diffusion of knowledge, however, there must be acquisition of knowledge, and we may at once ask the question, how far shall the university lend its aid in the encouragement of scientific research with a view to the enlargement of the boundaries of human knowledge? It is obvious that the force and energy of a great university must of necessity be given to the training of its students in the various departments of study laid down in the curriculum, and a university worthy of the name certainly cannot afford to devote the major part of its energies to the pursuit of scientific research, neither in my judgment would it be justified in so doing. By such a procedure, it would forfeit the right to the name of university, and its power for usefulness would be curtailed in no small measure

It is clear that loss in one direction might be counterbalanced by gain in another, but the true university must ever remain a place where the student can obtain knowledge of past discoveries, and of the sciences based thereon, together with that broad training which helps to make the educated man. In other words, the university cannot escape from its responsibility as an educational center for the diffusion of knowledge, and any attempt to transform the university into an institution for research alone would be detrimental to the best interests of higher education.

Shall the university, on the other hand, limit itself to routine instruction? To this there can be but one answer, and that is most emphatically, no. The true teacher of science, for example, must ever be a student, not only familiar with the past, but ever on the alert to interpret such signs as nature may make, quick to seize the opportunity to add to man's knowledge, to broaden and extend the limits of his chosen science, to keep in touch with the advances of the present and to harmonize these advances with the knowledge of the past, bearing clearly in mind that whatever is gained by scientific inquiry or research is never lost. As Sir Michael Foster has well said in a recent address, "what is gained by scientific inquiry is gained forever; it may be added to, it may seem to be covered up, but it can never be taken away."

The teacher of science who is content to devote himself entirely to the exposition of that which is known will never make an ideal teacher. He can never hope to arouse that enthusiasm among his students which comes from the man who adds to his power of teaching that love for his science and its advancement which prompts to steady, courageous application in the unravelling of nature's secrets. This influence for good upon the man himself is not to be overlooked, for I take it that the university has a selfish interest, if no other, in the intellectual development and advancement of the teacher who presides over this or that department of science. The pursuit of scientific inquiry, under proper conditions, tends to the development of moral courage and steadfast endurance; it is a school of discipline which leads to the acquisition of strength and power, which helps to make a man master of himself and at the same time obedient to nature's ways. As Professor Foster has said, men of science, though in themselves no stronger or better than other men, "possess a strength which is not their own, but is that of the science whose servants they are. Even in his apprenticeship the scientific inquirer, while learning what has been done before his time, if he learns it aright, so learns it that what is known may serve him not only as a vantage ground whence to push off into the unknown, but also as a compass to guide him in his course. And when fitted for his work he enters on inquiry itself, what a zealous, anxious guide, what a strict, and, because strict, helpful schoolmistress does nature make herself to him! Under her care every inquiry, whether it bring the inquirer to a happy issue or seem to end in nought, trains him for the next effort. She so orders her ways that each act of obedience to her makes the next act easier for him, and step by step she leads him on toward that perfect obedience which is complete mastery. Indeed, when we reflect on the potency of the discipline of scientific inquiry, we cease to wonder at the progress of scientific knowledge."

May we not, therefore, claim, from this standpoint alone, that the university should look with favorable eye upon scientific investigation within its boundaries, since its encouragement must lead to the development of strength and power in its teachers? Indeed, may we not urge that this recognition of the indirect advantages of scientific

research to the university should give way to direct and positive encouragement, an encouragement which should manifest itself in such an allotment of routine duties as would afford a reasonable amount of time for research to all suitable teachers in the university? I say *suitable* teachers, and, speaking as a physiologist, I should like to raise the question, whether the teacher of an experimental science, like physiology, if he is truly a suitable teacher, must not be an investigator also. Do not the two of necessity go together? And must not the university, if at all zealous for the character of the instruction offered within its walls, see to it that its teachers of science are not merely adepts at expounding that which is known, but are equally ambitious to open up new paths of knowledge in their respective departments of science?

Another, and more direct, reason why the university should encourage and aid scientific investigation is that by so doing it enlarges its own scope of usefulness as an educational center. The modern university, if it is to fulfill its purpose as an educational institution, must be well equipped with laboratories and those other facilities which go to make the teaching of an experimental science a success. What would the teaching of physiology and physiological chemistry, even in elementary form, amount to without the aid of laboratory facilities? The university, whether it looks with a favoring eye upon investigation or not, must have ample appliances for the teaching of the experimental sciences, and the more complete the equipment the better adapted is the university for carrying on its legitimate work. Moreover, the university of to-day is called upon to provide instruction for more advanced students; men and women who are themselves looking forward to the possibility of becoming teachers, who are anxious to learn the methods of scientific work, and who are desirous of demonstrating for themselves experimentally the facts upon which the important theories and hypotheses of their chosen science depend. For the realization of proper instruction in these respects, the university must provide suitable equipment if it is to live up to its high privileges, as well as have a suitable corps of instructors capable of leading on such advanced workers. The university must, therefore, have at hand all those appliances which are essential for research or investigation, and which the individual worker can rarely afford. Why should not these be utilized by competent investigators for scientific research? Fine laboratories and fine apparatus are of value only so far as they contribute to the spread of knowledge, and if they can be utilized for the acquisition of new facts, so much greater will be their usefulness, and so much more credit to the university that renders them available. But, having the appliances, should not the university make strenuous efforts even to encourage research; not passive encouragement, but direct, positive encouragement, that will not rest until the laboratory is filled with earnest workers taking advantage of the various facilities provided? I think, yes, and it takes very little imagination to picture the direct and indirect advantages accruing both to the university and to science by the fulfillment of such a suggestion.

Contrast, as you easily can, the difference in the atmosphere between a physiological laboratory, for example, occupied solely by a class at stated intervals on certain days of the week, and the laboratory in which zealous workers are to be found, ever experimenting on new problems, spurred on continuously by the stimulating influence of new facts and new observations, making a rallying place for the earnest thinkers and workers who constitute an ever-present

example for the elementary workers in the science. Who can measure the influence for good which emanates from such a laboratory? Does not the university derive, both directly and indirectly, an inestimable advantage from such surroundings, and may we not justly claim that the university by such encouragement of research adds directly to its own power and strength, while at the same time aiding in the advancement of the science? Its scope of usefulness is thereby greatly enlarged; advanced workers in the science are attracted to the university, and even the routine instruction given to the various classes, both graduate and undergraduate, is influenced by the atmosphere of earnest endeavor which permeates the laboratory. The tone of the institution is raised, while both student and instructor feel the stimulating effects of that environment which permits the carrying out of successful scientific work.

Granting all this, the question may be asked, how *far* is it allowable for the university to extend aid in the encouragement of research? It seems to me that the answer to this question must depend upon the resources of the individual institutions. The university must be true to the primary object of its existence. It cannot overlook the fact that it was created for a specific purpose, and the fulfillment of that purpose must be its first care. All higher institutions of learning, however, are bound to recognize the necessity of providing means for the carrying on of original investigations in the various branches of science. I believe, as a rule, it is better for our scientific workers to be connected with the university, than to carry on their work in connection with a special research laboratory, with complete freedom from academic duties. I think higher education would suffer if research work was limited to special research laboratories, and the advancement of science would not be as rapid as under existing conditions, where the research worker must spend a portion of his time in careful retrospect. Just as work in investigation helps to make a better teacher, so, in my judgment, the necessity of giving instruction to a body of young workers helps to make a better investigator. It should be the duty of the university, however, so far as possible, to allow time and provide means for investigation, and by the aid of scholarships and fellowships, judiciously awarded, offer inducements for the younger workers to spend a portion of their time in scientific research.

Do not the results which have been obtained by scientific workers in connection with our own and foreign universities afford ample proof of the value of this method of encouraging investigation and advancing scientific knowledge? Consider, if you will, the results which have been attained during the last twenty years in physiology; the advancement made along so many lines and in so many different directions, and then glance at the names of the men who have carried out these investigations and note their positions in life. They are practically all university men; men who have carried on research work in connection with their academic duties, in some cases unaided, but frequently with the cooperation of younger workers, assistants, fellows, etc., to whom they have taught in this way the methods of scientific investigation. I have just received the Jahresbericht für Thierchemie for 1898, containing the record of investigation for that year in physiological chemistry. The book contains 850 pages filled with brief abstracts of the researches in this somewhat narrow field of investigation. Does not this record indicate that investigation is being encouraged? That the universities and other institutions of learning are consciously or unconsciously taking a position of helpfulness toward scientific research? I believe

this to be the case, and while we must admit that in this country there is not quite the same liberality as exists abroad, yet I believe that all of our more prominent institutions of learning are willing and anxious, so far as their means will allow, to foster the spirit of investigation, both for the personal advantage to be derived therefrom, and for the sake of advancing the knowledge of science in its various departments. Certainly, the university cannot afford to take any position other than that of helpfulness towards scientific research, or manifest any disposition other than one of coöperation in the attempts that are made to advance the boundaries of human knowledge.

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EDUCATION as a preparation for conduct involves a fitting in respect to the two all-important factors by which conduct is determined. The educated man differentiates himself from the uneducated by the greater range and variety and by the intrinsic character of the influences to which he is responsive, and again by his mode of response to these influences and to the ordinary and extraordinary events and situations which our common environment presents. The receptive side of education is the more tangible and therefore apt to absorb attention beyond its due. It is so obviously important—especially in days like these, when there is such an endless series of things which it is necessary and useful to know—to furnish the individual with the maximum opportunities of acquiring information, that the problem that is apt to be relatively neglected is that of fitting him to use what he acquires, of making his stock of knowledge not a burden to be carried, but part of the strength that carries.

In the realm of education action and reaction are not necessarily equal; the individual may be exposed to wholesome and inspiring influences and yet derive from them neither health nor strength. A thorough education includes a training in both action and reaction; it educates one to be widely and deeply and yet critically receptive, to be judiciously and ably and yet creatively expressive. From the first to the last it considers both these aspects; feeling and knowing, observing and assimilating must step by step be complemented by doing and experimenting, by coördinating and originating. However true that the response presupposes the stimulus, yet the latter alone in the complicated conditions here pertinent will not produce it; it requires a strengthening of the reaction impulse, a guidance of the executive capacities.

To indicate the application of this principle to the elementary and intermediate phases of education is no part of the present discussion; and yet it may be in place to record my conviction that the furtherance of the responsive and originative functions in these stages of education is itself an important aid to the proper recognition of the place of investigation in the university. If from kindergarten to common school, and from these to high school and college, coördinative thinking could be successfully taught, if each step of knowledge could be made to yield an increase in the capacity to handle and arrange one's thoughts, then the necessity of keeping aglow the flames thus kindled, of laying stress upon originality and achievement in the university would more easily gain due recognition.

It is apparent that I claim as an important function of investigative work in the university its directive influence upon collegiate and university studies; and the recognition of this function on the part of the university authorities must always be a prominent motive for the proper provision of opportunities for investigation. From whatever other points of view it may be or

become the duty of the leading institutions of learning to contribute to the advancement of the boundaries of knowledge, the pedagogical motive will never lose its pertinence. But whether for the strengthening of its internal educational structure, or as a proper expansion of the university sphere of influence, there will always remain a close community of method and interest in all provision for research. That community is the furtherance of the investigative spirit. Fruitful investigation flourishes only in a proper soil and blossoms profusely only in a congenial atmosphere. One cannot have investigation without investigators; in some directions money may provide the materials, for the lack of which investigation must go halting, but in all directions investigators must be both born and trained. The inspiring intellectual life of our foremost universities certainly offers a most congenial atmosphere for the growth of that investigative spirit; the furtherance of that spirit is an indispensable factor in a worthy national and cultural progress.

It thus becomes not a supplementary duty but the very purpose of the university to provide an environment so thoroughly suited to the growth of investigation that it cannot but become its natural habitat. Research is indispensable to a university. says President Eliot, "because a university which is not a place of research will not long continue to be a good place of teaching; and, secondly, because this incessant, quiet, single-minded search after new truth is the condition of both material and intellectual progress for the nation and for the race."

It will be well to examine somewhat more closely the two aspects of investigation which I have selected for special emphasis —investigation for training and investigation for discovery. The working ideal of American universities is to provide their students with the maximum opportunities and privileges of which their degree of maturity and responsibility enables them to profit; and at the same time we continue the guidance of their progress in ever more indirect but no less efficient manner, until they strike out confidently, and as a rule creditably, in their chosen walks of life. We have not been tempted to imitate the German system which makes the passage from gymnasium to university an abrupt change from set tasks and stringent discipline to complete liberty with little guidance and no control. While it is proper that conventional ceremonies and new privileges should add zest to the assumption of the toga virilis, it is not proper that mistakes should be encouraged, nor that, for lack of a gradual transition, time and energy and strength should go astray. Men and women should have the liberty of making mistakes; there is a very real danger in over-guidance as well as in license. But the golden mean between these, though a narrow path, is broad enough to be readily found.

In the ideal which American universities attempt to realize, there are to be guide-posts enough to give the young explorer a confident feeling that others have trod the path before him, and to prevent useless wanderings into by-paths and *culs-de-sac*, and yet not enough to take away the incentive of independence and adventure, nor to lose the slightest opportunity to foster self-reliance and courage. It is necessary to understand this ideal and the consequent attitude of both guide and guided to appreciate the function in the university of investigation for training. For it seems to me that no other aspect of university studies can so readily be adapted to this ideal as the investigative aspect. I mean by this not merely the one topic that forms the basis of a thesis (which in the nature of things must often be quite detailed and not comprehensively significant);

but also the research attitude of the seminary, the participation in the problems of fellow-workers in the laboratory and study, the preparation for lectures and demonstrations, the presentation of technical material before clubs and societies, the critical digest of current contributions to learning and the tentative but stimulating first steps in productive authorship. In all these activities the attitude of the student is participative and expressive; not only absorbent but responsive; he must do and dare, he must count and weigh, he must thrust and parry; he is no longer wholly a spectator nor an auditor, he has a part, though a minor one, on the stage; and even the acquaintance with *the scene-painting* and *stage-carpentering* is a useful one for the training of the actor. It is in the special adaptation of investigation to accomplish these ends, to round out the motor side of education, that I see its pedagogical value. Research under judicious guidance is a training in coördination, a training in self-reliance, a training in readiness and resource, a training in reserve and critical ability, a training in construction and expression. It gives zest and dignity to what might otherwise seem to be insipid drudgery; by presenting conditions which must be met as best one can, investigation becomes a stern discourager of hesitancy; by its constant reference to and dependence upon the errors and outgrown opinions of the past, it is a wise encourager of caution and foresight. It teaches both how to look and how to leap. It maketh the full, and the ready, and the exact man. It would be unwise to forget that other aspects of university studies and university life contribute an essential quantum to the furtherance of the same qualities; but considering it with reference to its fitness in a systematic course of higher education, to elicit the full whole-souled response of ambitious youth, and in requiring just that proper measure of guidance and independence suitable to the capacities and purposes of university students, the position of investigation for mental training and discipline cannot hold a subordinate place.

Regarding investigation for discovery, I desire only to touch upon one or two aspects of it which are not so commonly associated with the term as they should be. While there is something to be said—in many departments much to be said—for investigation as a prudent and practical investment, there is no danger in a commercial democracy that this will remain unsaid. It is only in its relations to its constituency that it becomes important for the university to emphasize this aspect of investigations. Still less legitimate is it for a worthy university to exploit the contributions to knowledge which it has been fortunate to have developed within itself as an advertisement of its merits, not in this respect mainly but in general. There is no feature in the management of American universities that in my mind so easily arouses disgust and despair as this much varied but always objectionable heralding of their opportunities and successes. This field may properly be left to the manufacturers of proprietary and dietary specialties.

Investigation for discovery is a university function because of its incentive to the highest activity of those who in their several departments approach the confines of acquired knowledge and attempt to extend or to modify them; because of its contribution to the totality of the university spirit which permeates and stimulates every output of its energies; and, independently of these, because the advancement of learning by the creative capacities of the men of greatest endowment is in itself as proper a function of a university as teaching or the maintenance of libraries and museums.

Regarding its relation to the individual development of the professor, it would be

foolish to ignore the fact that teaching and research do not always make an harmonious pair. There will always be in letters and in science a group of men, often marked by genius as her own, who are keenly sensitive to the restraints and routine of instruction. Lowell said that being a professor was not good for him; it damped the gunpowder of his mind, so that "when it took fire at all (which wasn't often), [it] drawled off in an unwilling fuse instead of leaping to meet the first spark." The joy of feeling that the marks of the ball and chain had worn off induced him to write, "If I were a profane man, I should say, 'Darn the College!'" Some mutterings of similar import may occasionally be overheard in the vicinity of laboratories and lecture rooms. The best teacher is not always an investigator, nor the best investigator a teacher. The university should be broad enough to provide for men of both types and set each to work at that which he does best. And yet, because of its influence upon the totality of the university spirit, I believe that in the long run the fruits of instruction will be choicest when they have been ripened in the sunshine of investigation.

To what extent universities will be willing to encourage investigation as a complementary obligation to their other functions is largely a practical question; it depends upon means of support, it depends upon a public spirit liberal enough to appreciate and provide for its development in a spirit of the husbandman who plants the tree the fruits of which he shall not live to enjoy. 'Serit arbores quae seclo prosint alteri.' There are welcome signs that such a spirit is not foreign to our civilization, and that this is one of the respects in which the twentieth century may be expected to exceed the achievements of the nineteenth.

So far as I have attempted to crystallize my contribution to this symposium it may be said to center about these points: Investigation constitutes a motor or expressive factor in education at a stage in which that factor becomes particularly significant. It occupies an important place in the university by reason of its disciplinary value in the direction of self-reliant activity. The place of investigation in building up the spirit that makes for the safest and sanest progress is no less conspicuous. Investigation for discovery is a function coordinate in worth with other purposes of a university, and is more likely than almost anything else to keep the mind of the professor from 'drawling off in an unwilling fuse,' and to make it ready to leap to meet the first spark.

Joseph Jastrow.

University of Wisconsin.

It may be conceded in the beginning of this discussion that a modern university is an institution which devotes attention to all subjects information upon which can be systematized or reduced to a science, and that it is constantly striving to extend the boundaries of knowledge in every branch of human inquiry.

In its strictly educational function it develops a proper conception of these subjects in the minds of its students by the logical and inspired presentation of certain basal facts and underlying principles, with which the learner may build up the mental edifice representing the structural aspect of each subject in its completeness or incompleteness.

With a fairly general agreement upon these points it might be said that the subject for discussion is one which vitally concerns the integrity of the university, and any question of the abstract relation of the university to investigation would imply a most serious state of affairs. I take it for granted, however, that the real theme for

consideration is not the ethical relation of the university to research, since its obligations in the matter are invariable and undeniable, but rather one of the practicability and pedagogical expediency of carrying out this obligation.

Can the facilities of a university be used to advantage in the furtherance of research, and what influence does effort of this character exert upon its pedagogical functions?

The most prominent feature in the majority of our universities under their present organization is undoubtedly their academic department, in which the older, often miscalled the elementary, parts of the subjects are presented in a manner which absorbs the greater proportion of the facilities of the institution. The intent of such instruction is most commendable in its thoroughness and honesty of purpose, but here the good and honest intention, as with many others blindly followed, leads to a most iniquitous ending. No university of standing fills its chairs with men who are not prominent by the results of their investigations and active in their present prosecution. Having proceeded so far wisely and well, the administration then falters in its high purpose, and permits, rather insists that practically all of the energy of its members should be expended in the more or less mechanical duties attendant upon elementary instruction, especially in natural sciences, and fails entirely to provide either opportunity or facilities for the development of research work and its use in the presentation of the subjects. Such failure may be due to financial disability, though administrative lapses of judgment are not unknown or infrequent. In either case it is unfair and unfortunate to such a degree as to stretch the conception of honesty to its utmost limits, and to make the name of the university a travesty. Such non-appreciation of the actual importance of investigation is most conducive to stagnation, or indeed it may be taken as a symptom of it, and its deadening, thwarting effect is doing more to retard the development of the American university than any other one cause.

The presentation of any subject by an instructor who is not participating in its development will lack freshness of treatment, sharp distinctions between established and speculative deductions, will be more or less dogmatic, and will fall far short of its possible value, both for culture work and professional training. To this sweeping statement I am bound to add that there are a few teachers, not investigators, whose apparent success in instruction is due to an enduring and contagious enthusiasm which implants a permanent interest in a subject, in the mind of a student, which may lead him to follow it later and elsewhere to a more orderly and natural attack, from which he will gain a proper perspective for the first time. The arousing of enthusiasm and the imparting of information do not constitute the highest form of instruction however, and the teacher who does no more, fails not only in his special office, but also in his duty to bear a share in carrying out the obligations of the institution to society.

So far as investigation as a method of teaching is concerned, it is to be said that the acquisition and systematization of information gained in this manner, have a value both for culture and professional training lacking in any other method. It is a procedure by which the student is led to grasp the chief concepts included in a subject, the principles to be deduced from their orderly arrangement, to trace the manner in which every increment of new fact or advanced thought has been accumulated, and to follow the technique of this development in making his own acquaintance with the subject in its known aspects. So far he has been an investigator merely as a matter of discipline. Later he may project his activities beyond the boundaries of the

subject, and by contributions of his own winning, alter its limits and make a readjustment of its generalizations possible and necessary. The value of this investigating, or find out for himself, method of learning is too well established to need more than mention at this time; a value clearly conceded by its almost universal usage. Whether or not a student should be led into the specialization necessary to make discoveries, in his undergraduate days, is a question which may be answered only in the light of information as to his training, his purposes, and his mental capacity. The same may be said of the graduate student, except that the value of investigation for discovery is more immediate in his case if his graduate work logically follows his earlier training.

With the realization of the value of research in the university, it may be said that no worker who is thoroughly in earnest will fail to find means of attack upon some of the problems pressing in upon him, and to use this method in the presentation of his subject, no matter under what straitened circumstances he may find himself. The investigator who does not show this adaptability will certainly encounter ample opportunities for unhappiness.

With a devotion to research in its faculties it needs but the expressed appreciation of the administration to promote the pedagogical practice of investigation to a creditable degree, even if the material facilities are lacking. The extension of investigation to a point where it may actually contribute to the development of a branch of knowledge will depend very largely upon the actual financial resources of the institution, although the born investigator is not easily turned from his path. In any case the needs of a university for research facilities are quite as elemental and quite as pressing as for libraries, chapels, memorial halls, gymnasiums, or any other part of the institution's mechanism, and should receive corresponding attention from those in charge of its organization and administration.

The following statements may be made in conclusion:

1. One of the primal duties of the university is the furtherance of research.

2. The presentation of subjects by instructors not engaged in research will lack originality of treatment and will not be properly inductive.

3. Investigation is itself a method of advanced teaching by which a student comes to a full realization of the structural aspect and relations of a subject, participates in its development, strengthens his mental grasp and broadens his powers of generalization; a method by which the highest form of culture and training is secured.

4. Investigation is, therefore, not only an obligation of the university to society and to its students, but also one of its most effective weapons.

5. Any tendency to the restriction or curtailment of the opportunities for research is to be regarded as a most alarming retrograde movement, which may in time vastly impair the usefulness of the institution compelled to take this step, and is certainly indicative of disabled function or evasion of one of the plainest duties of the university.

D. T. MacDougal.
N. Y. Botanical Gardens.

It is hardly necessary to emphasize here the importance of investigation as a part of the training of the university student.

Training in research methods is chiefly valuable in that it stimulates the perception and the imagination and increases the power of self-guidance and immediate productivity. As a means of instruction it is slow and cumbersome and often fails to accomplish its object.

With the rapid growth, in recent years,

of the spirit of research, instruction in the methods of research is regarded as an essential part of the teachers' university training. The same kind of instruction is being rapidly transplanted into the college curriculum, where it may form part of the work of advanced students during their junior and senior years.

We shall not try to point out here the value of research to the university, or to discuss what may be done to give it new scope and direction. Let us rather inquire whether there is not a tendency to confound the university attitude toward investigation as a method of training, with that of the learned society or academy toward research as an end, and whether, as a result of this confusion, our higher educational institutions are not substituting too extensively a training in investigation for more direct methods of instruction.

The criticism may be fairly made that in research work an enormous amount of time is devoted to mechanical details that do not yield adequate returns, either in instruction or in training; that much of this work is begun before the student is properly prepared to undertake it, and done at the expense of the best opportunity he is likely to have of acquiring a broad, sympathetic culture, and a secure foundation knowledge of the subject in which he proposes to specialize; and finally, that the research work to which the student devotes so much of his time rarely, if ever, serves as a preparation for the kind of work by which he expects to earn a living,—namely, teaching in the college or secondary schools.

It seems to me that such criticisms are largely justified, and that they are specially applicable to the biological student, whom I shall have in mind in the discussion that follows.

This is mainly due to the nature of biological work, and to the character of the biologist. The latter is generally an enthusiast who follows his subject for its own sake, without hope of the large financial rewards of the inventive chemist or physicist. In rare cases he may be a man of wealth and leisure, but more generally he has very moderate means and is without the best preliminary training. In the great majority of cases, he must earn his living by teaching, and use his leisure time only for research.

In biology the frontier separating the known from the unknown is everywhere close at hand, and new methods of research make it easy for comparatively untrained workers, with a little guidance, to bring important facts to light.

It is not necessary to devote the long years of training required in music and art, to make the eye and hand of the biologist effective instruments for the performance of his work, and the apprehension of the mere materials with which he deals, taken alone, does not make great demands on his mental resources.

The daily occupation of the biologist may be so absorbing, that once he begins to section and stain, and put things safely away in bottles, he is likely to keep on doing so till he dies.

There is, therefore, a great temptation for the biological student to begin his creative work at an early period, and he is eager to do so because it gratifies his pride to be investigating something, and because, on the whole, investigation is a very entertaining occupation. The instructor is not likely to oppose his inclinations in this direction, since he finds it an easy way of keeping the student busy, and incidentally of clearing up little problems he has no time to work out for himself.

But there is probably no other subject in which there is greater danger of too early specialiization than biology, because there is no other science which sends its roots more deeply or intricately into other sci-

ences, or in which the personal equation, the character and training of the man, exerts a greater influence over the interpretation of results.

As the biologist's greatest skill is shown in the marshaling and weighing of a multitude of what must always remain incomplete and fragmentary data, his best preparation for such work will be the formation of that sound judgment which comes from a wide knowledge of his special subjects, and something more than the mere vocabulary of related ones.

The college courses do not usually give the required training, not for lack of time, but because so much time is wasted in getting ready to teach, and in observing the mouthings of science, that there is none left to hear what she has to say.

In some instances the instructor apparently tries to find out how long he can instruct without telling anything, and how long he can keep the student guessing what he is expected to see. After the student has made careful drawings of various organs and covered them with unintelligible names, he is often left to draw his own conclusions as to their meaning and function. This method may satisfy the student's curiosity to get a good interior view of the organization of an earthworm, but it does not enable him to discover what the science of biology has to say on the subject. It is as though one should begin a course in the science of football by requiring the student to make careful drawings of the stitching on the ball, and to section its germ layers, and then leave him to form his own notions as to how the game is played. Such a method is said to be of value in cultivating the powers of observation. But if the teacher of biology would teach biology only, and let the powers of observation alone, better results would be obtained. In my own judgment, you can hardly tell a student too much, or tell it too quickly, provided you tell it so that he can understand.

In the university the student often suffers from a similar lack of direct instruction. He generally finds that two kinds of courses are open to him: in one the treatment of the subject is so elementary that he can afford to ignore it; in the other some subdivision of it is discussed in great detail, and perhaps necessitates the expenditure of so much time and energy in the use of investigation methods that he does not want it, or cannot afford the time to take it.

In these courses, the instructor prides himself on giving the very latest report of the hour, with much controversial matter, better suited for the archives of some learned society than to be detailed in the class or lecture room. A prolonged diet of this kind is depressing, and is apt to leave in the mind of the student a succession of vague impressions of small educational value, and a feeling that it is more important that a certain investigator should receive full credit for having made a discovery than it is to give that discovery its due weight and position.

It has been said that biological instruction in America is not what it pretends to be, because the botanical side of the subject is neglected and most of the time given to zoology. But even the zoological instruction, that is supposed to be biological, is itself one-sided, since it may be treated from the purely morphological standpoint, ignoring altogether the experimental, physiological and ecological sides of the subject.

With all this special work goes a great deal of technique, something that readily degenerates into an interminable puttering over different methods, with very little attention given to the real questions to be solved by them.

On reaching the university the student's

first thought is to obtain some problem for his doctor's thesis, and, if he is fortunate, in the selection or assignment of a workable subject, and can obtain material to work with, his best energies are henceforth centered round that particular work, for he is led to believe that his future career depends largely on his discovering at once something of importance.

He feels that his time has been thrown away if at the end of a certain period he has no results on hand worth publishing. In the absence of such results and in his haste to get his degree, there is danger that after prolonged meditation he may unconsciously supply the deficiency by giving to his discoveries an importance they do not possess. By padding his paper with personal and irrelevant details, or by picking an unnecessary quarrel with his predecessors, and with the aid of an elaborate historical summary, he can generally get together an article of sufficient dimensions to produce a favorable impression on the biological community, excepting, of course, the half dozen or so individuals that read it.

In his research work the student is sustained by the thought that he is carrying on some profound investigation. But his work is largely mechanical. It may require a great deal of patience, a little manual skill, and perhaps some intelligence, but it very rarely shows any genuine originality. The student is really seeing and doing what he is told for he has not sufficient knowledge of his subject to steer his own course, or to clearly grasp the significance of the question at issue. Much of the research work of the faithful student type is of this nature. In fact, the instructor does the research, and the student the manual labor.

Another evil likely to arise from the overemphasis of research work is the danger of a great waste of time and energy on sterile problems. If it is downright cruelty, as Huxley says, to add one unnecessary hour to the work of the medical student, it is no less an offense to assign a line of special inquiry to a candidate for the doctor's degree with a possibility that at the end of one or two years his chances of getting the degree are as far off as ever, because through no fault of his own the work gave negative results, or because his results have been anticipated elsewhere. Another student, more fortunate in the assignment of his problem, may get his degree with the expenditure of half the time and labor.

Of course it may be urged that in most cases no one can know whether a given problem will be fruitful or not till it has been tried, and the candidate must take his chances. He must, no doubt, take his chances in after life, and he accepts the conditions more or less cheerfully, provided he is not asked to wager more time and strength on the hazard than are honestly his.

Meantime the candidate for a doctor's degree has been so absorbed in his research work, that he has not had time to think about his own development or his examinations. It is usually assumed that, when the time comes, 'a few weeks hard plugging will fix that all right,' and experience generally justifies the assumption. In a case that came directly under my own observation, a Japanese student of zoology was to demonstrate his knowledge of botany by describing how they cultivated tea in Japan.

After two or three years of investigation, the graduate student is liberated with an exaggerated idea of his own importance as a contributor to the world's store of knowledge, and quite untrained in the only work he is likely to do well, or even have a chance to try, namely, teaching in the secondary schools.

The layman, looking for a teacher with an up to date equipment for his work, may be impressed by the doctor's volumi-

nous treatise, but he will probably discover, when it is too late, that his candidate has but one imposing garment to conceal his unfitness for the work required, or, worse still, may find that he does not want to teach at all, but to investigate.

It may take several years for such a misfit teacher to adjust himself to his proper environment, and to discover that it is worth more to be a good neighbor and a useful man in the community than it is to be known in Germany.

In conclusion, therefore, it seems to me that by the over-emphasis of research the university is in danger of sacrificing the sound, symmetrical education of the individual for the sake of a too rapid growth of science. The university student should be trained in the methods of investigation, because it may give him fertility and power, not because it is his business or duty to contribute something new to the world's store of knowledge.

As the value of his contribution may or may not afford a measure of his originality or of his ability to teach, the university should not insist too rigidly on an original contribution as a requirement for the doctor's degree, and should eliminate every possible element of chance that may deprive the candidate of his well-earned license to teach, or that may unnecessarily prolong his term of apprenticeship.

The examination for the doctor's degree should precede rather than follow the approval of a thesis, in order to check too early specialization and an undue haste in the publication of fragmentary research work.

The biological material already available for teaching should be condensed and put into logical order for purposes of more direct instruction, and the educational requirements of the medical man, the teacher, and the professional investigator should, so far as necessary, be met separately.

The physiological and experimental sides of biology should receive greater attention, and that kind of out-door work on living animals in their natural surroundings, for which the marine and lake laboratories offer such excellent opportunities, should be specially developed, because among other reasons, of its bearing on the nature work in the public schools. The work done in these laboratories should be formally recognized as part of the requirements for the higher degrees, and the laboratories themselves grafted on to the university and college so as to form as much a part of their equipment as do the library and museum. Results of the greatest importance for biology, in all its relations to education, will surely follow coöperation in this direction.

Wm. Patten.

Dartmouth College.

AMERICAN MATHEMATICAL SOCIETY.

The sixth annual meeting of the American Mathematical Society was held at Columbia University on Thursday, December 28, 1899. On the same and the following day the Chicago Section met at the University of Chicago. Occurring in the holidays, these two meetings are more easily attended than those of other seasons, and afford better opportunities for personal conference and discussion. The annual meeting offers the additional interest of the election of officers, the presentation of annual reports which regularly bear testimony to the remarkable prosperity of the Society, and the general marking of the close of one year of progress and the opening of another. An especially attractive feature of this year's annual meeting was the scholarly Presidential Address of President R. S. Woodward on 'The Century's Progress in Applied Mathematics.' This address, which appears in the present number of Science, as well as in the next number of the *Bulletin* of the Society, was delivered before

an appreciative audience of nearly eighty persons, the members of the American Physical Society attending, by invitation, in a body. During the reading of the address and of Professor Pupin's paper, the chair was occupied by President H. A. Rowland, of the Physical Society. As predicted in the report of the October meeting, the relations of these two societies are becoming more and more intimate and cordial, a tendency which cannot be too highly commended. The results are mutually beneficial. The attendance of members of the Mathematical Society increased more than seventy per cent. over last year, this Society furnishing nearly one-half of the total attendance at the meeting of both bodies.

At the annual election the following officers and members of the Council were chosen: President, R. S. Woodward; First Vice-President, E. H. Moore; Second Vice-President, T. S. Fiske; Secretary, F. N. Cole; Treasurer, W. S. Dennett; Librarian, Pomeroy Laden; Committee of Publication, F. N. Cole, Alexander Ziwet, F. Morley; Members of the Council to serve for three years, Simon Newcomb, Oscar Bolza, L. A. Wait. Suitable resolutions were adopted on the retirement of Professor Jacoby from the office of Treasurer after a service dating from the founding of the Society.

The Council announced the election of the following persons to membership in the Society: Professor William Beebe, Yale University; Dr. J. V. Collins, State Normal School, Stevens Point, Wis.; Professor A. R. Forsyth, Trinity College, Cambridge, England; Professor M. W. Haskell, University of California; Mr. C. A. Noble, University of California; Miss E. N. Martin, Ph.D., Ardmore, Pa.; Mr. E. B. Wilson, Yale University; Miss R. G. Wood, New Haven, Conn. Four applications for membership were reported. The total membership of the Society is now 342, a gain of 27 during the year. About 110 papers were presented before the Society during the year as against 83 in 1898.

The first number of the *Transactions* is now in press and will appear in January. Later numbers will appear at intervals of three months.

The following papers were presented at the Annual Meeting:

(1) DR. G. A. MILLER: 'On the groups which have the same groups of isomorphisms.'

(2) PROFESSOR MAXIME BÔCHER: 'On regular singular points of linear differential equations of the second order whose coefficients are not necessarily analytic.'

(3) DR. VIRGIL SNYDER: 'On cyclical quartic surfaces in space of n dimensions.'

(4) DR. VIRGIL SNYDER: 'On the geometry of the circle.'

(5) MR. W. B. FITE: 'A proof that the commutator subgroup of a group may contain operators which are not commutators.'

(6) J. E. CAMPBELL, M.A.: 'On the types of linear partial differential equations of the second order (in three independent variables) which are unaltered by the transformations of a continuous group.'

(7) PROFESSOR L. E. DICKSON: 'Proof of the existence of the Galois field of order p^r for every integer r and prime number p.'

(8) DR. E. M. BLAKE: 'On plane movements whose point loci are of order not greater than four.'

(9) PROFESSOR R. S. WOODWARD: Presidential Address: 'The century's progress in applied mathematics.'

(10) PROFESSOR M. I. PUPIN: 'The propagation of electrical waves over non-uniform conductors.'

(11) PROFESSOR HENRY TABER: 'The singular transformation of a group generated by infinitesimal transformations.'

(12) DR. J. I. HUTCHINSON: 'On certain relations among the theta constants.'

(13) PROFESSOR E. O. LOVETT: 'Singular solutions of Monge equations.'

F. N. COLE,
Secretary.
COLUMBIA UNIVERSITY.

SCIENTIFIC BOOKS.

Everyday Butterflies. A Group of Biographies. By SAMUEL HUBBARD SCUDDER. Boston and New York, Houghton, Mifflin & Company. 1899. 12mo. Pp. viii + 386. 9 plates, 23 figures; 48 figures in text. Price, $2.00.

This tasteful little volume contains an account of the life-history, habits, and distribution of sixty-two species of the commoner butterflies, which are found in the Eastern States and the Canadian provinces of Quebec and Ontario. It is illustrated by nine plates, eight of which are done in colors, the other being a carefully executed and faithful representation in black and white of an enlargement of the interesting chrysalis of *Feniseca tarquinius*, the curious aphidivorous habits of the larva of which are fully explained by the author. The illustrations in the text are numerous and excellent, and, with the plates, will enable the reader to easily identify the species when encountered in nature.

The study of butterflies is every year gathering new devotees, especially from the rapidly-growing leisure class, and the ranks of the young in our schools and colleges. No field of observation is more accessible and interesting, and none more likely to yield valuable results, from the standpoint of the biologist, than that of entomology. Books, like the one before us, which combine scientific accuracy with a grateful flavor of the woods and the fields, can not fail to stimulate those who are their happy possessors to make researches, which will give charm and delight to life, and may prove of positive scientific interest.

Everything which falls from the pen of Dr. Scudder possesses the merit of literary grace, and, with but very few exceptions, absolute scientific accuracy. If any adverse criticism in general could be passed upon the writings of our learned friend, it is that in his zeal for precision of description and thoroughness of treatment he at times becomes a little prolix. This, however, is a trait wholly absent from the pages of the present book, which are sprightly and popular in style, while profoundly instructive.

Issue must be taken with two statements made by the author on page 281. In speaking of the chrysalis of *Feniseca tarquinius* he says: "Curiously enough, a similar ape's face is seen in the chrysalis of an African butterfly of another genus not very closely related to *Feniseca*, and in an Indian species of the same Oriental genus. Now, in these two cases there is a strong probability that their larval food is plant lice." The reference is to the chrysalis of *Spalgis s-signata*, Holland = *S. lemolea*, H. H. Druce, which I had the pleasure of describing and figuring in *Psyche* Vol. VI., p. 201, Plate IV., and to the chrysalis of *Spalgis epius*, Westwood, described and figured by Aitken in the eighth volume of the *Journal* of the Bombay Natural History Society, Plate A. A careful examination of the structural peculiarities and of the preliminary stages of the genus *Spalgis* shows that it is very closely related to our North American genus *Feniseca*, and any general classification of the lepidoptera belonging to the family Lycænidæ which did not place these genera in propinquity would be in error. The statement of the author that in the case of the two species of *Spalgis* mentioned "there is a strong probability that their larval food is plant lice," overlooks the fact that in both cases the aphidivorous habits of the larvæ have been positively ascertained.

Points like these relating to the habits of exotic species, which are only alluded to in passing, do not in the slightest degree affect the value of the book for the circle of readers for which it is particularly intended, and it may be recommended as altogether one of the most pleasing and instructive contributions made in recent months to a branch of science which is daily growing in importance and popularity.

W. J. Holland.

Carnegie Museum, Pittsburg.

Practical Exercises in Elementary Meteorology. Ginn & Co., Boston. 1899. Pp. xiii + 199.

One does not expect a laboratory manual to be interesting, yet Mr. Ward's volume will prove attractive reading to any one interested in the teaching of meteorology. It contains materials for laboratory work for all school ages and includes the exercises that within a few years constituted the laboratory work in Mr. Ward's course at Harvard.

The author does himself injustice when he states the object of his book is "to lead the pupil to the independent discovery of the most important facts in our ordinary weather conditions." The very judicious comments that

accompany the exercises tend rather to the rational end of illustrating the laws of meteorology and the method of meteorological study. The well-considered suggestions to teachers propose that in primary schools the attention of pupils be called on occasion to the more obvious relations of the various weather elements to one another and to us. This as a preparation for the exercises of this volume.

Parts I. and II. suggest observations, instrumental and uninstrumental, to be made by one and another member of the class from day to day and kept in a permanent record throughout grammar and high school years. Mr. Ward has prepared numerous questions designed to bring out the simpler relations of the various elements.

Part III.—Exercises in the construction of weather maps—is presumably to be used in high school years. A table of meteorological data for six consecutive days at all weather bureau stations throughout the country is printed at the end of chapter III. (not chapter VIII., as stands printed always in the text). From this pupils are to construct on blank weather maps the isotherms and isobars for each day and the corresponding temperature and pressure gradients. Other blank maps are to be filled out with wind arrows for each day, and still others with the signs for clear and cloudy sky, etc. Besides these construction exercises others are based on the comparative study of the maps thus drawn.

Part IV. contains Correlations of the Weather Elements and Weather Forecasting. These exercises follow naturally on the preceding, going to published weather maps for their data and tending to illustrate the cyclonic and anticyclonic groups of phenomena and their relationships.

These are very valuable exercises from the nature of the results sought and from the fact that they have that definite character which the young student demands. Generalities are his abhorrence, and while all his studies are in the direction of training to generalize from sufficient data he must be allowed a firm footing on particulars at the outset. The demand that he *formulate a general rule* (p. 117) is one that would leave many a high school pupil bewildered. Perhaps he could do it if told in other words.

Some of the problems in Part V. will be beyond the range of many pupils for this reason of their general character. Moreover, as they seek valid results on questions of importance, such as the relation of relative humidity to the direction of the wind, some use should be made of more extended collections of data, made more carefully than is practicable for school classes. It is a pity to base inductions on any but the best of data. I presume all who are teaching young people to make observations are agreed that the immediate object is to train their faculties and show them the scientific method rather than to acquire results. Indeed, it seems to me important that pupils should be led to recognize clearly the rude character of their work as compared with good standards. For this reason it is especially desirable to avoid drudging at observational and mechanical work. Only so much observation is desirable as will help the pupil to understand the process. When it comes to induction he should use the best results specialists have been able to produce. For similar reasons in some of the weather map exercises in Part III. use might be made of the government maps rather than of those produced by the pupil himself, as some of these will be too bad to use and most of them less easily read than the printed maps. I find classes of 13 and 14 years require three fifty-minute periods for the first satisfactory production of one day's isotherms. To reproduce six such days and then six more for isobars and yet more for other elements is to impose task-work. Most teachers will be content with fewer such tasks and as soon as the principle is grasped pass on to use the printed maps.

Mr. Ward has not claimed, however, to give us exercises in shape for immediate use, but rather to offer material from which we could select according to our needs. The materials he offers are abundant and available.

The descriptions of instruments are very clear and simple, and the historic notes and the comments on phenomena and relations between man and the weather very interesting.

Among the instruments one is rather sur-

prised to see the nephoscope, nor is maker or price indicated in the list of instruments. It is a pity to put a doubly-folded sheet like that in Chapter III. in a school-book. It will certainly be torn in the first year. By printing on both sides one fold might have been avoided and there is no good reason why all the data might not have been printed in the text as wanted day by day.

The fact that so many problems are worked out in the book makes it easier reading but will require the books to be closely watched in the class-room.

The Weather Bureau Meteorological Tables are inserted at the end of the book with an excellent appendix on the 'Equipment of a Meteorological Laboratory.'

The book should prove valuable to every teacher of meteorology.

M. S. W. Jefferson.

Elmwood, Mass., December 19, 1899.

Bacteria, especially as they are related to the Economy of Nature, to Industrial Processes and to the Public Health. By George Newman, M.D., Demonstrator of Bacteriology, King's College, London. The Science Series. New York, G. P. Putnam's Sons; London, John Murray. 1899. Pp. 348.

The fact that bacteria are concerned in a variety of natural processes and do not devote themselves exclusively to the causation of disease is beginning to touch the popular imagination and to create a demand for treatises that shall deal with the subject of bacteriology from a general biological standpoint rather than a strictly medical one. An attempt to meet this need has been made in the present instance. Dr. Newman discusses, under separate chapter-heads: The Biology of Bacteria, Bacteria in Water, Bacteria in the Air, Bacteria and Fermentation, Bacteria in the Soil, and Bacteria in Milk, Milk Products and other Foods. These six chapters cover 239 pages out of 348. A chapter is then given to The Question of Immunity and Antitoxins, which is followed, by what seems a singular inversion, with one on Bacteria and Disease, and the book ends with a chapter on Disinfection. Many topics of great interest are considered in these pages, and the author's selection of material and mode of treatment will command general approval. The book is marred, however, by a lax and involved style and contains so many errors of statement as to call seriously for revision. On page 30, for example, it is stated that "boiling for thirty to sixty minutes will kill all bacilli and all spores," and on page 79, "moist heat at the boiling point maintained for five minutes will kill all bacteria and their spores." These statements are not in accord and neither is correct. On page 16 it is erroneously stated that "*Micrococcus agilis* is the only coccus which has flagella and active motion." In the description of Van Ermengem's method of staining flagella (p. 63) it is probably through a typographical slip that a 25.5 per cent. solution of silver nitrate is recommended, and surely the use of boric acid in place of osmic acid in the fixing bath is an unusual procedure. It is hardly a careful form of statement to refer to the power of the tetanus bacillus to produce disease as its 'regular function' (p. 32). The author's definition of the antitoxin unit (p. 263) is incorrect. It is not necessary to multiply instances, but it is to be hoped that subsequent editions may find some of these blemishes removed, since they unquestionably impair the value of an otherwise interesting and useful book.

Two examples of the author's somewhat enigmatic style may be given: "Yet, whilst this general fact is true, we must emphasize at the outset the possibility and practicability of securing absolutely pure sterile milk. Recently some milking was carried out under strict antiseptic precautions, with the above sterile result" (p. 181). "*Budding* occurs in some kinds of yeast, and would be classified by some authorities under spore formation, but in practice it is so obviously a 'budding' that it may be so classified" (p. 16).

E. O. J.

A Treatise on Crystallography. By W. J. Lewis, M.A., Professor of Mineralogy in the University of Cambridge. Cambridge Natural Science Manuals, Geological Series. Cambridge: At the University Press. 1899. 4to. Pp. xii + 612.

This new text-book of crystallography presents the modern views as to the classification of

crystals based on the principles of symmetry. It is devoted exclusively to the geometrical relations of crystal forms and to methods of determining these relations and of representing them graphically.

In the first nine chapters the general properties of crystals are described, including very full discussions of symmetry relations and of the properties of zones. The discussion is geometrical rather than analytical and follows more or less closely the treatises of Miller and Story-Maskelyne. In Chapters VI. and VII., treating of crystal drawing and methods of projection, no mention is made of the gnomonic projection, which now occupies an important place in crystallographic discussion.

The treatment of the general optical and physical properties of crystals of the different systems contained in Chapter X. is very brief and seems hardly adequate in a work of this character.

Chapters XI. to XVIII. are devoted to descriptions of the thirty-two classes of crystals. The classification of these types is essentially that of Groth. A feature of this part of the work is the presentation of a great many examples of crystals of various substances in each class, each crystal being worked out in detail with all the logarithmic computations necessary for the determination of its elements and the indices of its forms. Directions for drawing the forms are also not infrequently given after their determination, and a great deal of useful information in practical crystallography may be found scattered through these examples. But their number seems rather more than necessary, adds very much to the bulk of the book and so scatters the desired information as to reduce its usefulness.

In the final chapter on Goniometers but scant justice is done to the theodolite goniometer, no reference being made to the admirable graphic methods of discussing measurements made with it developed by Federow and Goldschmidt.

A complete index concludes the volume. The excellent typography and text figures deserve a word of praise.

The book hardly commends itself to beginners in crytallography, being too elaborate in its treatment and too mathematical in its presentation. Its greatest service will be to more advanced students doing practical work in the study of crystals.

C. PALACHE.

SCIENTIFIC JOURNALS AND ARTICLES.

THE contents of the *American Journal of Science* for January are as follows:

'Products of the Explosion of Acetylene,' by W. G. Mixture.

'Glaciation of Central Idaho,' by G. H. Stone.

'Pogonia Ophioglossoides,' by T. Holm.

'Graftonite, a new Mineral from Grafton, New Hampshire, and its Intergrowth with Triphylite,' by S. L. Penfield.

'Explorations of the *Albatross* in the Pacific Ocean,' by A. Agassiz.

'Analyses of Italian Volcanic Rocks, II.'; by H. S. Washington.

'Constitution of the Ammonium Magnesium Arseniate of Analysis,' by M. Austin.

THE *Astrophysical Journal* for December contains the following articles:

'Robert Wilhelm Bunsen,' by Henry Crew.

'The Wave-Length of the Corona Line,' by C. A. Young.

'Density of Close Double Stars,' by Alexander Roberts.

'The Densities of the Variable Stars of the Algol Type,' by Henry Norris Russell.

'Note on the Spectrum of *P. Cygni*,' by A. Bélopolsky.

'Apparatus and Method for the Photographic Measurement of the Brightness of Surfaces,' by J. Hartmann.

'The Great Sun-Spot of September, 1898,' by J. Fényi.

'A Spectroscope of Fixed Deviation,' by Ph. Pellin and André Broca.

'Researches on the Arc-Spectra of the Metals,' by B. Hasselberg.

THE contents of *Appleton's Popular Science Monthly* for January include 'The Advance of Astronomy in the Nineteenth Century,' by Sir Robert Ball, 'The Applications of Explosives,' by Professor C. E. Munroe, 'Scenes on the Planets,' by Mr. Garrett P. Serviss, Professor Ward on 'Naturalism and Agnosticism,' by Mr. Herbert Spencer, and 'Old Rattler and the King Snake,' by President David Starr Jordan. The *Monthly* is somewhat altered in appearance, and the price is $3.00 per annum. We trust that its influence may be correspondingly increased.

St. Nicholas magazine, which is so popular with young people and has on the whole exercised such an excellent influence, will with the new year add a department of natural history, under the editorship of Mr. Edward F. Bigelow, editor of *Popular Science*. Six pages, monthly, will be devoted to this new department. Two of these will be given up to the out-door world; two more to indoor study and research, both in nature and science; one to correspondence from the children; and one to a department of 'Questions and Answers.'

SOCIETIES AND ACADEMIES.

PHILOSOPHICAL SOCIETY OF WASHINGTON.

The annual meeting of the Society was held at the Cosmos Club on December 23, 1899. The usual reports of the Secretaries and Treasurer were read and an Amendment to the Constitution proposed at the last annual meeting was adopted. By this action membership in the General Committee is subject to new conditions as far as the ex-Presidents of the Society are concerned.

The election of officers for the coming year resulted as follows:

President: G. M. Sternberg, Surgeon General U. S. A.; *Vice-Presidents:* H. S. Pritchett, Superintendent Coast and Geodetic Survey; C. D. Walcott, Director Geological Survey; L. F. Ward, Geological Survey; Richard Rathbun, Smithsonian Institution; *Secretaries:* J. E. Watkins, National Museum; E. D. Preston, Coast and Geodetic Survey; *General Committee:* Cyrus Adler, Library of Congress; W. A. DeCaindry, War Department; J. H. Gore, Columbia University; G. W. Littlehales, Navy Department; H. M. Paul, Naval Observatory; F. W. True, National Museum; C. K. Wead, Patent Office; I. Winston, Coast and Geodetic Survey; C. F. Marvin, Weather Bureau.

E. D. Preston,
Secretary.

SCIENCE CLUB OF THE UNIVERSITY OF WISCONSIN.

The December meeting of the Science Club of the University of Wisconsin was held on the evening of December 18th, the program of the evening being a paper by Mr. S. M. Babcock, dealing with the fat globules of milk.

Mr. Babcock stated that, although the fat globules of milk were discovered about two hundred years ago, no accurate knowledge of their structure, number or size was gained until quite recently. Two hypotheses have been advanced regarding their structure. One is that they are surrounded by a thin membrane of albuminous matter which prevents their uniting when they come into contact and protects them from the solvent action of ether when this is shaken with milk, unless a little acid or alkali is first added to dissolve the membrane. The other hypothesis holds that the globules are free particles of fat emulsified with the serum. It was shown that all phenomena which have been considered to favor a membrane are such as occur also in artificial emulsions, where no true membrane can exist if the fat globules are as small as those of milk, and it was, therefore, concluded that milk is an emulsion. The method of counting fat globules by means of capillary tubes was described and the circumstances which affect their number and size were discussed with the aid of lantern slides.

Wm. H. Hobbs.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

At the meeting of the Academy of Science of St. Louis of December 18, 1899, Dr. Amand Ravold addressed the Academy on the necessity and means of filtering and otherwise purifying water, especially with reference to freeing it from bacteria, for municipal purposes. The speaker explained the sand-bed filter system as used in Germany and England, and the American mechanical system, represented by two commercial devices. The Wormser filter plate was also described and its characteristics were considered.

William Trelease,
Recording Secretary.

DISCUSSION AND CORRESPONDENCE.

OBSERVATIONS WITH THE MERIDIAN CIRCLE.

To the Editor of Science: In reading Professor Keeler's most interesting report upon the results of the Lick Observatory, as printed in Science for November 10, 1899, I find a statement on page 669 which, if not a misprint, eclipses all work of a similar character.

In connection with that portion touching upon the Meridian Circle, Professor Keeler states that during the year ending last September, and upon 106 nights, 6000 observations were made with the Meridian Circle.

Now the question I would submit, and upon which I would request information, does Professor Keeler wish it understood that 6000 star places were observed in that time, or are these numbers of observations made up of the determination of the right ascension, declination, nadir point, collimation, level and azimuth, each individual determination of these quantities to be counted as one observation?

The above figures give as a nightly average 57 observations, and from my experience four or five observations per hour—I mean a complete determination in both right ascension and declination, when one is not working with an assistant and not in zone work—is about the limit.

When it is taken into consideration that one observer sets his circle, reads four microscopes, observes nine or eleven transits, makes two or more bisections in zenith distance, and records all these, reads his level at least once every hour, observes his collimation twice in an evenning's work, an average of 57 observations per night is almost, if not quite, unrivaled.

But, as I said before, perhaps what Professor Keeler wished to convey by the word 'observations' is not what I have construed it, a complete determination of the two coördinates of the star place, but may contain two, three or four quantities, which he calls observations.

GEO. A. HILL.

NAVAL OBSERVATORY, WASHINGTON, D. C.

NOTE ON THE FOREGOING LETTER BY PROFESSOR HILL.

IN the part of my report to which Professor Hill refers in his letter, one observation means one complete determination of both coördinates of a star. A complete observation of the nadir (zenith) point and level is also, in accordance with the usual custom, counted as one observation. Collimation and flexure determinations and *mire* readings have not been included.

A reference to our records for the year covered by my report shows that the average number of stars, completely observed in both coördinates during this period by Professor Tucker, was fifty per night. With an assistant reading the microscopes the average number was sixty-two per night of from four to five working hours. The observations, as shown by their probable errors on complete reduction, are of the highest order of precision.

Doubtless this is quick work, but I believe that it is by no means of unprecedented rapidity. It is moreover obvious that a comparison of the work of different instruments, on the basis of such figures as those given by Professor Hill, may be quite misleading, since the rapidity with which observations can be made depends largely on the character of the work which is being done. With a full list like that of Mr. Tucker's during the past year, the stars culminate more rapidly than they can be observed, so that the list has to be gone over several times. The rate of observation then depends upon the observer's quickness and skill. With a list which contains many gaps, stars have to be waited for, and the rate depends upon the list alone.

JAMES E. KEELER.

DARK LIGHTNING.

TO THE EDITOR OF SCIENCE: My attention was drawn to Mr. Clayden's work by an article in *Nature* in which reference was made to a communication in one of the photographic journals. The note in the *Philosophical Magazine* I had somehow overlooked.

Mr. Clayden in his letter states that he was unable to obtain any results with the calcium light or with sunlight, and suggests that there may exist some difference between light from such a source and a source whose excitement is electrical, and that it is not safe to assume that the time factor is the only one, until the image of some non-electrical source has been reversed. I cannot see much difference between the calcium light and the arc, for in both we are dealing with an incandescent solid. To settle the matter definitely I have repeated the experiment with the revolving disc, using a calcium light, and obtained perfect reversed images of the slit on the first trial. Mr. Clayden's failure to get reversal with sources other than the spark was due, I imagine, to a too long exposure. The duration must be something less than 1/15000

sec. The exact point at which the reversing action begins can be easily determined by the revolving disc, and will be investigated shortly by one of our students.

R. W. Wood.

SCIENCE IN THE DAILY PRESS.

To the Editor of Science: In view of the appearance of several articles in the daily press relating to the case of the rapid calculator, Arthur Griffith, and purporting to be written by us, we beg to say that we have written no such article and have seen neither copy nor proof of any such article. We have given to reporters, when asked to do so, the principal facts reported before the Psychological Association. The published accounts have varying degrees of accuracy, a few of them being substantially correct. We are impelled to make this disavowal, for the reason that in some instances we are represented as making claims in regard to the case which we have never made. Persons interested are referred to the Proceedings of the Psychological Association and to the fuller statement of results presently to appear.

E. H. Lindley,
Wm. L. Bryan.

University of Indiana, Jan. 4, 1900.

'NEWSPAPER SCIENCE.'

To the Editor of Science: Some weeks ago in Science, and more recently in *The Psychological Review*, Professor J. H. Hyslop condemned in rather sweeping terms what he called 'newspaper science.' He was incited to do so by the publication of an erroneous and annoying report about himself. But while his irritation was certainly justified, his utterances were a trifle indiscriminate. And it is due both to the daily press, which he thus censures, and to the readers of your pages that attention be called to this fact.

It is true that certain papers indulge in untruthful and sensational stories about scientific men and scientific discoveries. But there are others that do not. To classify these two kinds of newspapers together betrays a lack of careful observation, or a wrong use of the logical faculty; perhaps both. Such a proceeding is hardly worthy of a man who pretends to a strictly scientific method in his ordinary work.

The fact is that, though they are only too scarce, one can easily find both newspapers and newspaper men who possess as keen a perception of the eternal beauty of truth, and are animated by as lively a sense of responsibility to the public, as the average professional scientist. A wider recognition of this fact is needed, not merely in the interests of justice, but in those of science also.

Now the number of persons who read technical reports and periodicals—astronomical, electrical, engineering, medical, psychological, and so on—is only about one-hundredth, or only a thousandth, as great as those who see only the daily papers. The vast majority of people could not understand this literature, anyhow. It needs interpretation and adaptation to popular comprehension. The daily paper, therefore, forms a highly important medium of communication between the original investigator and the general public; and, for better or for worse, it will always perform that function. If, then, men who are themselves engaged in scientific researches of value to mankind, or are identified with institutions devoted to the deposit of scientific collections, would abstain from aiding papers that are notoriously reckless, and encourage by word and definite favors those which treat scientific matters intelligently, conscientiously and accurately, they would promote the diffusion of knowledge to a far greater degree than is now possible, and check the very abuses of which Professor Hyslop complains. Not merely in their comments, but also in their active policy, professional scientists can do much to reform 'newspaper science' if they will.

Amateur.

New York, January 5, 1900.

BOTANICAL NOTES.

A NEW SOUTHERN FLORA.

Professor Tracy has prepared a little book under the title of 'Flora of the Southern United States' for use with Bergen's 'Elements of Botany' (Ginn & Company), which is intended to be used as an elementary manual for field work in systematic botany in the public schools.

The author recognizes the fact that "the ability to identify and name plants is not the object of botanical study, but it is a great assistance in attaining the knowledge which the true student of botany is seeking—an understanding of the laws of life in the vegetable kingdom." He has made it possible by means of keys and easy descriptions for the beginner to obtain some ideas as to how plants are classified, what botanists think as to the relationship of plant groups, and how to proceed in identifying an unknown plant. As far as it goes the book is a modern presentation of taxonomic botany. It deals with seed-plants only. Even the ferns so commonly included in manuals of this kind are not included, while the pupil gets no hint whatever of anything lower in the scale of plant life. This is a mistake, but a very common one, in botanical manuals, and we must perhaps overlook it for the present. It is pleasant to find a modern sequence of families (Engler and Prantl's) and a strictly modern nomenclature.

A NEW BOTANICAL JOURNAL.

WITH the December number the first volume of *Rhodora*, the new journal devoted to the botany of New England, was completed. The idea of a local botanical journal of high grade was a novelty, and its progress during the year was watched with much interest. Now at the end of its first volume we may look over what it has accomplished and judge as to whether a geographical limit is a wise one to be placed upon the field of a scientific journal. By far the greater number of articles deal with flowering plants, and are systematic rather than morphological, although the latter are by no means wanting. The ferns and mosses receive scanty notice, while the algæ and fungi are the subject of frequent papers and notes. Many of these papers have much more than local interest, and might with propriety have appeared in any botanical journal. Of course, there are some 'local notes,' some papers on 'noteworthy plants,' some on 'rare plants,' and some 'additions' to local floras. There is little if any of that species splitting which is too often the bane of local botany. The editorial announcement of a year ago stated that special attention would be given "to such plants as are newly recognized or imperfectly known within our limits, to the more precise determination of plant ranges, to brief revisions of groups in which specific and varietal limits require further definition, to corrections upon current manuals and local floras. to altitudinal distribution, plant associations and ecological problems." 'Ferns, mosses and thallophytes' were promised a share of attention. It is to the credit of the management that the program outlined at the outset has been so well carried out. *Rhodora* has shown that a geographically limited scientific journal may be successful and useful.

CHARLES E. BESSEY.

THE UNIVERSITY OF NEBRASKA.

THE CONFERRING OF UNIVERSITY DEGREES BY THE SMITHSONIAN INSTITUTION.

THE Chairman of the Senate Committee on the District of Columbia, Mr. McMillan, introduced, on January 2d, a bill entitled "An act to authorize the regents of the Smithsonian Institution to confer certain degrees and for other purposes." It provides:

"That the regents of the Smithsonian be, and they are hereby, authorized to appoint a board of five examiners, who shall, with the approval of the said regents, prepare and publish a schedule of courses of studies preparatory to the degrees of master of arts, master of science, doctor of philosophy and doctor of science. The said examiners shall from time to time hold examinations in the City of Washington for the said degrees; and, on the satisfactory completion by any candidate of the prescribed course of studies for either of the above mentioned degrees, shall recommend such a candidate to the regents of the Smithsonian Institution for such degrees. The said regents are hereby authorized to confer, under suitable regulations, the degrees above mentioned and also the honorary degree of doctor of laws. Provided, That no person shall be accepted as a candidate for the degree of master of arts or of doctor of philosophy who has not completed a course of study at least equivalent to the course of study required of candidates for corresponding degrees in the most advanced universities in the United States; and provided further, That the

degree of doctor of laws shall be conferred on no more than five persons in any one calendar year.

"Sec. 2. The members of the board of examiners shall hold office during the pleasure of the regents of the Smithsonian Institution. Each examiner shall devote his entire time to the duties of instruction and examination assigned to him by the said regents, and shall receive a salary of $4,000 per annum, except that the chairman of the board shall receive a salary of $5,000 per annum.

"Sec. 3. The said regents shall also appoint, subject to appropriations by Congress, such minor offices, and shall establish such rules, regulations and forms as may be necessary to carry out the purposes of this act. They shall also establish a schedule of reasonable fees to be paid by candidates for examination for degrees, which fees shall be paid into the treasury of the United States to the credit of the Smithsonian Institution.

"Sec. 4. The said regents are hereby authorized to accept and to administer any bequest or gift of real or personal property which may be made to them to establish lectureships, to endow chairs of instruction, to establish fellowships, scholarships or prizes, to purchase land, to erect buildings, or otherwise to carry out the provisions of this act.

"Sec. 5. The sum of $50,000, or so much thereof as may be necessary, is hereby appropriated out of any monies in the treasury not otherwise appropriated, to be expended as other public monies appropriated for the use of the Smithsonian are expended to carry out the purposes of this act."

THE UNIVERSITY OF NEBRASKA.

At the December meeting of the Regents of the University of Nebraska, no election was made of a chancellor to fill the vacancy caused by the resignation of Dr. George MacLean, in July. The committee on chancellor asked for more time.

Dr. Bessey, acting chancellor, reported upon the condition of the University. Six hundred and twenty-two new students entered the University during the fall term, and at the present time there are registered in all departments 1560 students, this not including the students present in the summer session, nor those registered in the School of Music and School of Agriculture (short course). The total registration for the year will probably reach about 2100. The registrations in scientific work are as follows: Botany, 153; Chemistry, 526; Entomology, 25; Geology, 100; Physics, 348; Zoology, 160; in technical lines, Civil Engineering, 54; Electrical Engineering, 70; Mechanical Engineering, 251; in languages, German, 629; Greek, 172; Latin, 407; French, 328; English, 1556; History, 570; Political Science, 215; Law, 151.

Among the material improvements during the year are the steam tunnels for carrying steam heat to the different halls on the campus, the completion of the interior work on Mechanic Arts Hall, and the erection of 'Experiment Station Hall,' and an additional power plant—the two buildings last named being on the University Farm.

In accordance with a report made by a committee of the faculty, the regents designated exactly the constitution of the faculties of the two four-year colleges ('Letters' and 'Science').

On Acting Chancellor Bessey's recommendation, plans were ordered drawn with reference to the eventual removal of the University from its present site in the city to its domain in the suburbs known as the 'University Farm.' Early removal is not contemplated, but all buildings and other improvements on this domain are to be made hereafter with reference to the future removal of the University to its new site.

The acting chancellor called attention to the desirability of continuing the University work throughout the year, as is done in the University of Chicago, and the regents appointed a committee to investigate the matter and to report at a future meeting.

Dr. William W. Hastings was given a short leave of absence to enable him to make anthropometric investigations in northern Mexico. Professor Nicholson, for many years head professor of Chemistry, was given, on his request, a leave of absence for one year, beginning January 1, 1900. During his absence Dr. John White is head professor of the department.

RECENT ADDITIONS TO THE AMERICAN MUSEUM.

THE second portion of the Cope collection containing the Fishes, Amphibia and Reptilia has recently been acquired by the American Museum of Natural History as the munificent gift of President Jesup. It includes 350 described species, represented in the majority of cases by the type specimens. The Amphibian collection is from the Permian formation of Texas, and represents many years' work by Cummings and other collectors. There are also large numbers of primitive reptiles belonging to the Proganausauria and other groups. The Trias is fairly well represented, mainly from Pennsylvania. The Jura is represented by collections both from the Colorado Sandstones and from the Como Beds. The former are the most valuable and in the most complete condition, including, especially, the type of *Camarasaurus* and types of other genera which Professor Cope described but never worked up. The Kansas Cretaceous is represented by a very large collection of Mosasaurs and Pterosaurs in fairly good condition and including many of Cope's types. From the Laramie is an especially fine Hadrosaur, a complete skeleton of Diclonius capable of being mounted, also remains of the Ceratopsia. From other parts of the Mesozoic and from the Tertiary are a great variety of reptile remains more or less complete, including some fine Belodontia, Crocodilia and Chelonia. This supplements the very large reptilian collection already made by the American Museum which will now be worked up for the first time.

At the same time there has been presented to the Museum, by Messrs. Havemeyer, Iselin, Dodge, James and Osborn, the valuable Pampean collection purchased by Professor Cope at the Paris Exposition of 1878. This was the first large exhibition in Europe from the Argentine Republic; it includes several entire skeletons, especially those of the great sabre-tooth tiger, *Machærodus*, and of *Lestodon*, and parts of the skeleton of *Toxodon*, also the carapace of several of the armored Edentates. This collection was mounted for exhibition in Paris and very carefully packed at the time of its purchase by Professor Cope; it has never been unboxed since.

Dr. O. P. Hay, formerly of the Field Columbian Museum, who for some time past has been working in the National Museum, has accepted a position in the American Museum as Assistant Curator of Vertebrate Paleontology and will be especially engaged in the arrangement of the Cope Mesozoic collection; he will enter upon his duties January 15th.

SCIENTIFIC NOTES AND NEWS.

MR. G. K. GILBERT, of the U. S. Geological Survey, has been elected president of the American Association for the Advancement of Science, to fill the vacancy caused by the death of Professor Edward Orton.

WITH the close of the year, Assistant Charles A. Schott, who for nearly fifty years has been the distinguished and energetic chief of the Computing Division of the Coast and Geodetic Survey, retired from that important position in order to devote his whole time to special scientific work. Under Mr. Schott's careful supervision and training has developed a corps of skilled computers equalled by no other scientific bureau. To his labors, perhaps, more than to any other one man's, is due the high scientific character of the results which the Survey has given to the world. The completion last year of the great arc, begun over a quarter of a century ago, marks an epoch in the history of the Division, and, the beginning of the triangulation on the 98th meridian, would seem to be a fitting occasion for relieving Mr. Schott of the burden which he has borne for so many years. His official career has been coincident with the development of the Survey, and his untiring zeal and fidelity have done much to bring about its present standard. Assistant Schott will now devote himself to the discussion of the eastern oblique arc (Maine to Louisiana) and a similar arc in California. His successor is Assistant John F. Hayford, who for several months past has occupied the position of Inspector of Geodetic work, and has thus had general supervision, under the Superintendent's direction, of the field geodetic operations. His assumption of the duties of chief of the Computing Division in addition to his previous duties gives him the supervision of the geodetic

operations from the inception of the plans and the beginning of the field work to the publication of the results, an arrangement which, doubtless, will be conducive to efficient coöperation of the field and office and to prompt publication of results. Mr. Hayford has had eight years' experience with the Survey both in field service and office work, and has, therefore, received excellent preparation for his present position.

INVITATIONS have now been sent for the memorial meeting in honor of the late Dr. Daniel Garrison Brinton, to be held in the hall of the Historical Society of Pennsylvania, Philadelphia, on Tuesday evening, January 16th. The American Philosophical Society issues the invitations on the part of

The University of Pennsylvania, The Academy of Natural Sciences, The Numismatic and Antiquarian Society, The Historical Society of Pennsylvania, The Geographical Society of Philadelphia, The Oriental Club of Philadelphia, Jefferson Medical College, The American Association for the Advancement of Science, The Smithsonian Institution, The Bureau of American Ethnology, The United States National Museum, The Anthropological Society of Washington, The American Folk-lore Society, The American Antiquarian Society, The New Jersey Historical Society, The New York Historical Society, The American Oriental Society, The Wyoming Historical and Geological Society, The Chester County Historical Society, The American Museum of Natural History, The Field Columbian Museum, The Peabody Museum of American Archæology and Ethnology, The Peabody Institute of Arts and Sciences, The Loyal Legion.

THE statue of Lavoisier, to be erected in Paris, will probably be unveiled in July of this year. The international subscription amounted to 98,000 francs.

SIR RICHARD THORNE THORNE, K.C.B., F.R.S., principal medical officer to the Local Government Board of England, and distinguished for his labors on behalf of public health, has died at the age of 58 years.

PRESIDENT MCKINLEY has designated the following officials to represent the United States Government at the International Medical Congress, which meets in Paris, in connection with the Exposition, August 2d, next, and to the congress of hygiene and demography, which assembles at the same place, August 10th: For the army Surgeon General Sternberg and Surgeon LaGarde; for the navy, Surgeon General Van Reypen; for the marine hospital service, Surgeon General Wyman and Passed Assistant Surgeon Rosenau.

MR. FRANK LENEY, of the Geological Department of the British Museum, has been appointed assistant curator of the Norwich Museum.

DR. LABOURAND has been appointed director of a laboratory newly established by the Municipal Council of Paris, his chief duties being to make inspections of the city schools with a view to diseases of the skin.

THE position of chemist, New York State Board of Health, will be filled on or about January 27th. The examination will consist entirely of practical questions relating to analysis of food products and questions relating to experience and training of the candidates.

AT a meeting of the American Ethnological Society, held December 19th, at the American Museum of Natural History, the following officers were elected for the ensuing year:

President, Mr. Morris K. Jesup; *First Vice-President*, General Grant Wilson; *Second Vice-President*, Professor Franz Boas; *Recording Secretary*, Livingston Farrand; *Corresponding Secretary*, Marshall H. Saville; *Treasurer*, Mr. Frederick Hyde, Jr.

THE Australasian Association for the Advancement of Science is holding its annual meeting this week at Melbourne, under the presidency of Mr. R. L. J. Ellery.

THE eighth International Geological Congress will be held in Paris from August 16th to 26th. The sessions will be divided into four sections, as follows: (1) General and technical geology; (2) stratigraphy and paleontology; (3) mineralogy and petrography; (4) economic geology and hydrography.

THE New York State Museum has recently acquired from Mr. C. J. Sarle an interesting collection of several hundred specimens representing a new crustacean fauna from dark shales at the base of the Salina beds of western New York. These contain numerous species of the merostoms *Eurypterus Pterygotus* and other genera, which have not before been observed.

THE German Imperial Government will contribute an annual subsidy of $5,000 toward the

Institute of Tropical Hygiene, to be opened at Hamburg on October 1st.

MR. MARSHALL H. SAVILLE left New York on December 22d for Mexico to conduct archæological investigations for the department of anthropology of the American Museum of Natural History.

PROFESSOR FREDERICK STARR, of the University of Chicago, is on an exploring trip in Mexico to continue his anthropological researches.

REUTER'S AGENCY announces that the expedition of Baron Toll, organized for the exploration of the New Siberia Islands and Sannikoff Land, to which no man has yet penetrated, will set out in June next from a Norwegian port, whence it will proceed to the mouth of the Lena, on the banks of which river, at a point above the town of Yakutsk, it will pass the winter. During the summer of 1901 the expedition will begin its explorations towards the north, picking up *en route* a detachment which will be sent forward from the main body during March, with a sufficient supply of dogs.

THE Smithsonian Institution has issued a catalogue of its publications available for distribution in December, 1899. The catalogue can probably be obtained on application, and should be in the hands of men of science, as many valuable papers, reprints and monographs can be secured at a comparatively small price.

THE publishers, MM. Georges Carré and C. Naud, 3 rue Racine, Paris, propose to issue an *Annuaire des Mathématiciens*, containing the names, addresses, etc., of all who are engaged in studying or teaching mathematics. The publishers ask the coöperation of all mathematicians, who are requested to forward their names and addresses.

Nature reports that the Brussels Academy of Sciences has awarded the prize of six hundred francs, for an important contribution to geometry, to M. Léon Autonne, of the University of Lyons. The prize of six hundred francs for anatomical and systematic investigations of insects of the group Apterygota (Thysanura and Collembola) has been awarded to M. Victor Willem, of the University of Ghent. M. F. Keelhoff, of the same University, has been awarded the Prix Charles Lemaire (interest on twenty-five thousand francs) for a work entitled 'Note sur le travail des forces élastiques.' The decennial prize of five thousand francs for botanical science has been awarded to Professor Alfred Cogniaux; and a prize of the same value for chemistry and physics has been given to Professor Louis Henry. To fill vacancies caused by death, the Academy has elected as foreign associates in the section of mathematics and physics, Sir G. G. Stokes, Professor Moissan and Professor Jordan. In the section of natural sciences, M. C. Vanlair has been elected a *membre titulaire*, Professors Pelseneer and Gravis have been elected correspondents, and Sir John Murray and M. Maupas have been elected associates.

THE Berlin correspondent of the London *Times* states that the plan and details are now published of the vessel which is being built at the Howaldt Shipbuilding Yard at Kiel for the German Antarctic expedition. The ship in question will be built of wood, the only material strong and elastic enough to resist the pressure of the ice. In form she will be somewhat rounder than the *Fram*, and will not fall away towards the keel in the same manner. It will be remembered that at the Geographical Congress in Berlin, Dr. Nansen himself expressed the opinion that the shape of the *Fram* would not be suitable for the heavy weather of the southern seas. In order to strengthen the ship against the pressure of the ice, the middle deck will be built very nearly on the level of the water-line. Protection against floating ice will be afforded by a triple coating of oak, pitch-pine and South American greenwood, and the bow and stern will be especially protected by steel bands. The length of the ship will be about 46 meters, the breadth between 10 and 11 meters, and the draught about five meters. She will be constructed to carry coal and other stores sufficient for three years, and will contain accommodation for five scientific observers, five officers and a crew of about 20 men. Each of the scientific travelers and each of the officers will have his own cabin. Four rooms will be assigned to the crew. The engine and the boiler will be placed in the stern, between the living rooms. The center of the ship will be occupied by the rooms for scientific work and

the forecastle will contain space for 50 Arctic dogs. The ship will be rigged as a three-masted schooner. Two steam winches will serve the anchor and will also be used for scientific purposes. The ship will be illuminated throughout with electric light. The Howaldt Shipbuilding Yard, which is under a contract to have the ship built by the 1st of May, 1901, and fitted out not later than the end of August, 1901, has already begun the construction. A model of the vessel will be shown at the Paris Exhibition.

Lectures given or about to be given before the Royal Institution, London, are as follows: Mr. C. Vernon Beys, six Christmas lectures (specially adapted for young people) on Fluids in motion and at rest; Professor E. Ray Lankester, twelve lectures on the Structure and classification of fishes; Dr. W. H. R. Rivers, three lectures on the Senses of primitive man; Professor H. H. Turner, three lectures on Moddern astronomy; Dr. Charles Waldstein, three lectures on Recent excavations at Argive Heræum (in Greece), three lectures by Sir Hubert H. Parry; Mr. W. L. Courtney, three lectures on the Idea of tragedy in ancient and modern drama; the Right Hon. Lord Rayleigh, six lectures on Polarized light. The Friday evening meetings will begin on January 19th, when a discourse will be given by the Right Hon. Lord Rayleigh, on Flight; succeeding discourses will probably be given by the Hon. C. A. Parsons, Professor J. Reynolds Green, Mr. H. Warrington Smyth, Professor J. H. Poynting, Major Ronald Ross, Professor Frank Clowes, Sir Benjamin Stone, M.P., Professor J. Arthur Thomson, Sir A. Noble, Professor Dewar and others.

UNIVERSITY AND EDUCATIONAL NEWS.

Mr. John D. Rockefeller has given $100,000 to Columbia University to endow the chair of psychology.

Mr. Andrew Carnegie has given $300,000 to Cooper Union, New York City, and $200,000 has been contributed by Abram S. Hewitt and Mr. Edward Cooper. This will enable the Union to establish courses in mechanic arts.

Syracuse University receives $25,000 by the will of the late Erastus F. Holden, of Syracuse.

The Italian Parliament has voted a sum of 1,300,000 lire for the erection of new buildings for the University of Bologna.

President J. M. Crafts, of the Massachusetts Institute of Technology, has presented his resignation, to take effect at the close of the present academic year. In his letter of resignation, he says: "My reasons for taking this step at the time are founded upon my desire to return to purely scientific occupations. My term in office has shown me the wide field of educational problems, both within and outside the Institute, which should be studied, and I have found that such studies and the performance of administrative duties, although not in themselves burdensome, leave little freedom for the pursuit of experimental science. A choice must be made between administrative and scientific occupations, and it is the latter which I wish to choose."

Edwin Grant Dexter, A.M. (Brown), Ph.D. (Columbia), now of the State Normal College, Greeley, Colo., has been elected professor of pedagogy in the University of Illinois.

Mr. E. M. Blake, Ph.D., who was recently elected to an honorary fellowship in mathematics at Cornell University, has entered upon his work there. Mr. Blake received his doctor's degree from Columbia University in 1893, after which he spent two years there as instructor in Barnard College. He spent the year '95–'96 as a student in Leipzig, Berlin and Göttingen, and in '96–'98 was instructor in mathematics in Purdue University. Since leaving Purdue, Dr. Blake has been a student in Paris; his investigations thus far have been chiefly in kinematics.

By a recent Ministerial decree, M. Sergejevich, whose unpopularity with the students of the University of St. Petersburg is said to have been one of the chief causes of the disturbances that have occurred among them, has been relieved of his functions as Rector of the University of St. Petersburg. He has been succeeded by Professor Holmstein, who is credited with liberal tendencies.